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STENO AND THE PHILOSOPHERS

Edited by

RAPHAËLE ANDRAULT & MOGENS LÆRKE

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Cover illustration: portrait of Nicolas Steno, attributed to the de' Medici court painter Justus Sustermans, around 1670.

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Abbreviations

A Gottfried Wilhelm Leibniz, *Sämtliche Schriften und Briefe*, ed. Akademie der Wissenschaften, Berlin: Akademie-Verlag 1923—[?], followed by series and volume number in roman numerals.

AT René Descartes, *Œuvres*, eds. C. Adam and P. Tannery, new presentation by B. Rochot and P. Costabel, Paris: Vrin-CNRS 1964–1974.

EP Nicolas Steno, *Nicolai Stenonis epistolae et epistolae ad eum datae*, ed. G. Scherz, Copenhagen: Nordisk Verlag 1952.

GP Gottfried Wilhelm Leibniz, *Die philosophischen Schriften von G.W. Leibniz*, Berlin: Wiedman 1875–1890, re-edited by Hildesheim/New York: Georg Olms Verlag 1978.

KM Nicolas Steno, *Nicolaus Steno. Biography and Original Papers of a 17th Century Scientist*, eds. T. Kardel and P. Maquet, 1st edition, Heidelberg: Springer 2013.

OP Nicolas Steno, *Opera philosophica*, ed. V. Maar, Copenhagen: Tryde 1910.

OT Nicolas Steno, *Nicolai Stenonis opera theologica cum prooemiis ac notis Germanice scriptis. Tomus posterior*, eds. K. Larsen and G. Scherz, Copenhagen: Nyt Nordisk Forlag 1947.

List of Contributors

Raphaële Andrault

Researcher at the CNRS, based at the *Institut d'histoire des representations et des idées dans les modernités* (IHRIM, UMR 5317) at the ENS de Lyon. She is the author of *La vie selon la raison. Physiologie et métaphysique chez Spinoza et Leibniz* (Champion 2014) and *La raison des corps. Mécanisme et sciences médicales* (Vrin 2016). She has published a critical edition of Steno's *Discours sur l'anatomie du cerveau* (Classiques Garnier 2009) and co-edited two volumes: *Médecine et philosophie de la nature humaine, de l'Âge classique aux Lumières* (Classiques Garnier 2014) and *Spinoza/Leibniz. Rencontres, controverses, receptions* (Presses Universitaires de Paris-Sorbonne 2014).

Jakob Bek-Thomsen

Associate professor at Aarhus University, working on intellectual history of the early modern period, especially civic humanism and concepts of the self and society in relation to health and medicine. In 2012, he defended a PhD thesis at the Department of Culture and Society, Aarhus University, entitled *Nicolaus Steno and the making of an early modern career: Nature, knowledge and networks at the court of the Medici 1657–1672*. He has published "From flesh to fossils—Nicolaus Steno's anatomy of the Earth", in *Geological Society, London, Special Publications 2013*, v. 375, 289–305.

Daniel Garber

A. Watson J. Armour III University Professor at the Department of Philosophy at Princeton University. Garber's principal interests are the relations between philosophy, science, and society in the period of the Scientific Revolution. Garber is the author of *Descartes' Metaphysical Physics* (1992) and *Descartes Embodied* (2001), and is co-editor with Michael Ayers of the *Cambridge History of Seventeenth-Century Philosophy* (1998). Most recently he published *Leibniz: Body, Substance, Monad* (2009). Garber is also the co-editor with Donald Rutherford of the *Oxford Studies in Early Modern Philosophy*, an annual.

Vasiliki Grigoropoulou

Teaches Early Modern Philosophy at the National & Kapodistrian University of Athens. She has published various essays and papers on Descartes, Hobbes, Spinoza, Locke and Rousseau. She is the author of the following books: *Γνώση, Πάθη και Πολιτική στη φιλοσοφία του Σπινόζα* [*Knowledge, Passions and Politics in Spinoza's Philosophy*] (Athens 1999) and *Αγωγή και πολιτική στον Ρουσσώ* [*Ped-*

agogy and Politics in Rousseau] (Athens 2002). She has edited the following works: Spinoza, *Treatise on the Emendation of the Intellect* (Athens 2001; 6th ed. 2012); J.-J. Rousseau, *Du contrat social* (Athens 2004; 8th ed. 2012); Descartes, *Principia Philosophiæ*, Intro., transl. and notes (Athens 2012); Stuart Hampshire, *Spinoza and Spinozism* (Athens 2013). She has been a visiting scholar at the Universities of Pittsburgh, Cambridge and Princeton. Her recent research focuses on Spinoza and Stoicism.

Eric Jorink

Teylers' Professor of Enlightenment and Religion at Leiden University and researcher at the Huygens Institute for the History of the Netherlands. He has widely published on early modern scientific culture, including *Reading the Book of Nature in the Dutch Golden Age, 1575–1715* (2010) and, with Dirk van Miert (eds.), *Isaac Vossius (1618–1689) between Science and Scholarship* (2012). He is currently finishing a biography of Johannes Swammerdam (1637–1680).

Troels Kardel

Retired general practioner and lecturer in general medicine in Copenhagen. Studies on the scientific works and biography of Steno, especially on his theory of muscular contraction and method in science. Author of *Steno: Life—Science—Philosophy* (Munksgaard 1994), *Steno on Muscles* (American Philosophical Society 1994). He has recently published an English edition of all the scientific works by Steno, including the Steno biography by Gustav Scherz (with P. Maquet, *Nicolaus Steno. Biography and Original Papers of a 17th Century Scientist*, Springer 2013).

Mogens Lærke

Senior researcher at the CNRS, based at the *Institut d'histoire des representations et des idées dans les modernités* (IHRIM, UMR 5317) at the ENS de Lyon. Author of *Leibniz lecteur de Spinoza* (Champion 2008), *Les Lumières de Leibniz. Controverses avec Huet, Bayle, Regis et More* (Classiques Garnier 2015), and numerous articles and book chapters on early modern philosophy. Editor of *The Use of Censorship in the Enlightenment* (Brill 2009) and co-editor of *The Philosophy of the Young Leibniz* (Franz Steiner Verlag 2009), *Philosophy and its History* (Oxford University Press 2013), *Spinoza/Leibniz. Rencontres, controverses, réceptions* (Presses Universitaires de Paris-Sorbonne 2014), and *Leibniz: lectures et commentaires* (Vrin 2017).

Sebastian Olden-Jørgensen
Associate professor in early modern history at the Saxo Institute, History Section, Copenhagen University. Professor Olden-Jørgensen's main fields of interest are early modern political culture, history of science, church history, historiography and methodology. He has published several articles on Nicholas Steno, among them: "Die Konversion Niels Steensens (1667) und der frühneuzeitliche Deismus," in *Historisches Jahrbuch*, 121 (2001), 97–114, and "Nicholas Steno and René Descartes: A Cartesian perspective on Steno's scientific development," in Gary Rosenberg (ed.), *The Revolution in geology from the Renaissance to the Enlightenment*, Boulder: GSA Memoir 203, 2009, 149–157.

Justin E.H. Smith
Professor of Philosophy at the University of Paris VII—Denis Diderot. He is the author of *Divine Machines: Leibniz and the Sciences of Life* (Princeton University Press, 2011) and *Nature, Human Nature, and Human Difference: Early Modern Philosophy and the Invention of Race* (Princeton University Press 2015). He has edited or co-edited a number of volumes on the history of early modern philosophy.

Frank Sobiech
Research Assistant at the Chair for Church History and Patrology at the Theologische Fakultät Paderborn. His research focuses upon Christianity in the early modern period. He earned his Th.D. in Church history from the University of Münster with the study *Herz, Gott, Kreuz. Die Spiritualität des Anatomen, Geologen und Bischofs Dr. med. Niels Stensen (1638–86)* (Aschendorff 2004). His second book on Steno is *Radius in manu Dei. Ethos und Bioethik in Werk und Rezeption des Anatomen Niels Stensen (1638–1686)* (Aschendorff, 2013). Habilitation from the Faculty of Catholic Theology, University of Würzburg, with a thesis on Friedrich Spee SJ (1591–1635).

Pina Totaro
Senior Researcher in Philosophy at the ILIESI-CNR, Università di Roma Sapienza. Her research is oriented toward the study of modern philosophy with particular reference to the study of the history of Cartesianism and Spinozism. Recent publications include B. de Spinoza, *Compendio di grammatica della lingua ebraica*, eds. P. Totaro e M. Gargiulo (Firenze 2013); *«Sphaera». Forma Immagine e metafora tra medioevo ed età moderna*, eds. P. Totaro e L. Valente (Firenze 2012); L. Spruit and P. Totaro, *The Vatican Manuscript of Spinoza's* Ethica (Leiden-Boston 2011), and *Tradurre filosofia. Esperienze di traduzione di testi filosofici del Seicento e Settecento*, ed. P. Totaro (Firenze 2011).

Introduction

Raphaële Andrault and Mogens Lærke

This volume focuses on the Danish scientist and theologian Nicolas Steno (1638–1686) and his importance for seventeenth century philosophy and philosophers. Its aim is to study the intricate relations between philosophy, theology, and the emerging sciences (medicine and geology in particular) in the early modern Republic of Letters through the biographical prism of one of its most fascinating members. Concentrating on Steno's contributions to natural philosophy and his relations to philosophers, the volume thus portrays Steno not only as an influential scientist and theologian, but also as a natural philosopher who played a pivotal, albeit ambivalent, role in the intellectual networks of philosophers and natural scientists in the late seventeenth century.

Steno is one of the most celebrated anatomists of all time, known mostly for his discovery of the so-called *ductus stenonis* (a salivary duct), his study of brain anatomy in the *Discours sur l'anatomie du cerveau*, pronounced in 1665 and published in 1669, and his work in myology, in particular his description of the heart as a mere muscle in *De musculis & glandulis observationum specimen* (1664) and his geometrical model of muscle contraction in the *Elementorum myologiae specimen seu musculi descriptio geometrica* (1667).[1] Steno is also considered the father of modern paleontology and geology, mainly on account of his treatise *De solido intra solidum naturaliter contento dissertationis prodromus* (1669), where he, as the first, suggested that the stratification of rocks could be used for geological dating and showed the organic origin of fossils.

Steno was educated as a physician by Thomas Bartholin at the University of Copenhagen in 1656–1659, by Gerardus Blasius at the Amsterdam *Athenaeum Illustre* and by Franciscus de la Boë Sylvius and Johannes Van Horne at Leiden University in 1660–1664. While in Holland, he befriended a number of illustrious physicians, philosophers and anatomists, including Benedict de Spinoza and Johannes Swammerdam. After his studies, he undertook a *peregrinatio academica* that took him first to Paris, then to Saumur, Montpellier, and Florence. He acquired some fame in 1665 by his spectacular dexterity and anatomical skills when performing public dissections in Paris at the Académie de Thévénot. From 1666 to 1670, he lived mostly in Italy where he frequented the members of the *Accademia del Cimento* at the court of the Great Duke Ferdi-

1 See for instance Kardel, "Nicolas Steno's New Myology," pp. 37–64.

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nand II of Tuscany. It was during this period that he published his most important studies. Raised Lutheran, he converted to Roman Catholicism in 1667 but continued his scientific activities. Between 1672 and 1674 he performed dissections as a "Royal Anatomist" in Copenhagen. In 1675, he was ordained a priest. He became the preceptor of the Great Duke's son in Florence between 1675 and 1677. In 1677, however, after having been appointed bishop of Titiopolis and Vicar Apostolic of Northern Europe, he mostly stopped doing scientific work and focused on his ecclesiastical commitments. He lived first in Hanover (1677–1680), then in Münster (1680–1683). In 1683, Steno resigned from the church and was briefly involved in scientific work again. He died after an acute illness in 1686. Venerated by the Roman Catholic Church, he was beatified in 1988.

There is an extensive commentary literature on Steno. Until very recently, however, most of it focused either exclusively on his scientific work or entirely on his theological itinerary. Steno's philosophical position, as well as his importance for other seventeenth-century philosophers, remain largely unexplored. There are historical reasons for this lacuna. Among philosophers and historians of philosophy, Steno the anatomist has become an object of derision as the ridiculous anti-Cartesian who tried to prove Descartes wrong by slicing up brains and studying the pineal gland. As for Steno the Catholic, he is routinely described as a spectacular scientific talent gone completely to waste. Steno's reputation as a mediocre philosopher has partly been generated by Steno himself, notably by his open letter to his former friend Spinoza entitled *De Vera philosophia, ad novae philosophiae reformatorem* (1675), a text that not undeservedly earned him a reputation as a fideist.[2] The same reputation was also created and maintained by Gottfried Wilhelm Leibniz's uncharitable remarks in the influential *Essais de théodicée* (1710) according to which Steno "was a great anatomist, and very well versed in the natural sciences, but unfortunately he abandoned research and turned from a great physicist into a mediocre theologian."[3] It is, however, becoming increasingly clear, first, that Steno played a crucial role in the networks among late seventeenth century natural philosophers and, second, that assuming this role required considerably better philosophical abilities than those habitually attributed to him.

Recently, exciting new material about Steno's interactions with some of the major philosophers has been brought to light. Pina Totaro and Leen Spruit's 2011 edition of a previously unknown manuscript copy of Spinoza's *Ethica*

2 On Steno and Spinoza, see Totaro, "'Ho certi amici in Ollandia': Stensen and Spinoza—science verso faith," pp. 27–38; Klever, "Steno's Statements on Spinoza," pp. 303–313.

3 Leibniz, *Essais de Théodicée*, § 100, GP VI, p. 158.

deposited by Steno in the Vatican Library sometime around 1677 has raised new questions regarding Steno's role in relation to Spinoza and Ehrenfried Walther von Tschirnhaus, and generally regarding his role in the very first diffusion and reception of Spinoza's philosophical work prior to the publication of the *Opera posthuma* in late 1677.[4] Moreover, the constant progress of the Academy edition of Leibniz's *Sämtliche Schriften und Briefe* has in recent years brought to light previously unknown aspects of Steno's interactions with Leibniz in Hanover in the late 1670s.[5] All this new material has demonstrated the pressing need for a deeper exploration of Steno's central role in the networks among early modern natural philosophers.

The same need for reassessment is felt in relation to the question of Steno's own philosophical position. Among historians of philosophy and historians of science, there is an increasing interest in the natural philosophy of Descartes and, more generally, in Cartesian medical anthropology and physiology. While Steno's anti-Cartesian stance has previously been considered philosophically inept, recent work has highlighted the interest of Steno's *Discours sur l'anatomie du cerveau*.[6] Contrary to a reductive story familiar to historians of philosophy, when criticizing Descartes' dualism from the point of view of anatomy, Steno was not committing a category mistake. Descartes himself, as well as his followers, Louis de La Forge being the most prominent among them, addressed the problem of the mind-body union on the physiological level and considered the study of the brain and its functions paramount for resolving it. Moreover, Steno's opposition to Descartes was not as clear cut as it might appear at first sight. As Sebastian Olden-Jørgensen has shown, Steno's research on anatomy and geology first developed in a mechanist Cartesian framework, even though Steno became progressively more critical of Descartes.[7] Finally, by taking an empirical, purely observation-based approach, Steno was raising major epistemological issues at the very heart of the Cartesians' natural philosophy. Thus,

4 See Spruit and Totaro (eds.), *The Vatican Manuscript of Spinoza's Ethica*; Totaro, "On the Recently Discovered Vatican Manuscript of Spinoza's Ethics," pp. 465–476; Totaro, L. Spruit and P. Steenbakkers, "L'*Ethica* di Spinoza in un manoscritto dela Bibliotheca Apostolica Vaticana (*VAT. LAT. 12838*)," pp. 583–610; Lærke, "The Vatican Manuscript of Spinoza's *Ethica*," pp. 843–847.

5 On Leibniz and Steno, see Lærke, *infra*. See also Vad, "Polidore and Théophile: The Rationalist and the Faithful Observer," pp. 39–47. See also Lærke, "*Quod non omnia possibilia ad existentiam perveniant*," pp. 1–30.

6 See Andrault, "Introduction" in Sténon, *Discours sur l'anatomie du cerveau* 2009.

7 Olden-Jørgensen, "Nicholas Steno and René Descartes," pp. 149–157, here p. 149.

recent work on Steno as a natural philosopher has given rise to a renewed interest in his scientific epistemology, including its relations to his theological position, summarized in his 1673 *Prooemium*. Frank Sobiech and Stefano Miniati have reevaluated the traditional question of the *condordia rationis et fidei* in the light of new research in the Florentine libraries and archives.[8] In prolongation of their work, there are still persistent problems to solve with respect to how Steno's philosophy of science evolved in parallel to his growing theological aspirations. For example, what precise role did the intellectual life of the so-called *politici* in Amsterdam play for Steno's later conversion? And is it really the case that Steno, as is often assumed, completely abandoned scientific research after 1677?

Gathering contributions from researchers of different nationalities and from different disciplines, the ambition of this volume is to consider a wide variety of philosophical aspects of Steno's intellectual enterprise. Readers will perhaps detect some tensions among the chapters: some stress the importance of Steno's stay in Leiden; others insist on the influence of the *Academia del Cimento* in Florence; some emphasize the conflict between natural history and Steno's catholic proselytism, while others stress the theological motivations underlying Steno's anatomical research at the beginning of his career. These tensions partly reflect the contradictory accounts that Steno gave of his own conversion and which researchers weigh differently. The present volume does, however, follow one common interpretive line, namely the conviction that, in Steno, as is the case with many intellectuals of the period, there was a strong connection between natural philosophy and Christian apologetics, and that this connection was played out in the political context of intense confessional struggles.[9] Moreover, going beyond the case of Steno, the volume aims at correcting some widespread but erroneous notions about his intellectual context, especially about the so-called "scientific academies," be they Dutch, French or Italian.

In the first main section we study the intellectual itinerary that led Steno from being a prominent modern natural philosopher to becoming an influential Roman Catholic bishop, focusing in particular on his networks and encounters with other intellectuals. Eric Jorink focuses on the young Steno's formative stay in Holland in the period from 1660 to 1664, with particular emphasis on his

8 See Sobiech, *Herz, Gott, Kreuz*; Sobiech, "Nicholas Steno's (1638–1686) Conversion," pp. 25–31; Miniati, *Nicholas Steno's Challenge for Truth*.

9 See e.g. E. Jorink, *Reading the Book of Nature*.

relations to the circles around the Blasius family and to "heterodox" thinkers such as Adriaan Koerbagh and Spinoza. Jorink provides a detailed description of the intellectual culture Steno found himself immersed in, mainly based on Johannes Blasius' *Album amicorum* and the travel diary by Steno's close friend, Ole Borch. Next, turning to Steno's relations to Swammerdam, Jorink points out striking parallels between the intellectual itineraries of the two men, both of whom went through profound religious crises at some point in their career, prompted by doubts about the ability of the new mechanicist, Cartesian scientific paradigm to provide the confirmation of divine providence and glorification of God's works which motivated their study of the book of nature. While Steno originated from a largely homogeneous Lutheran culture in Denmark, Swammerdam was brought up in the diverse and "political" religious culture of the Netherlands, where considerable less emphasis was put on the confessional structures and ecclesiastical institutions in relation to faith and devotion. Partly because of these differences in religious culture, their respective personal crises led them on very different paths: Steno embraced the Roman Catholic Church; Swammerdam, after a disappointing flirt with Antoinette Bourignon's mystical sect, finally adhered to the "invisible church" of the non-confessional sects in Holland, becoming, with Kolakowski's expression, a "Christian without a church."

In his chapter on Steno's conversion to Catholicism, Sebastian Olden-Jørgensen returns to the much-debated question of what exactly prompted the Danish scientist to convert. Considering the available sources in detail as well as the different—if not outright contradictory—accounts given by Steno himself in different texts, Olden-Jørgensen favors the explanation provided in a letter to Leibniz where Steno stresses the importance of his stay in the Netherlands and the meeting with the liberal Dutch intellectual culture, arguing that the originally Lutheran Steno went through a "deist" phase—here mainly relying on Grotius for defining deism—before turning to the Roman Catholic faith. It is worth noting how Olden-Jørgensen's description of the so-called Dutch *politici*, whose dangerous religious culture the post-conversion Steno denounced, is strikingly close to Jorink's account of the "political way of living" in the latter's chapter on the young Steno's stay in Holland in 1660–1664.

Mogens Lærke studies the relations between Leibniz and Steno, with particular emphasis on the period from 1677 to around 1680, when they frequented each other personally at the Court of Hanover. Lærke thus develops the biographical backdrop for Leibniz's famous quip in the 1710 *Essais de théodicée*, already quoted above. He stresses in particular how Leibniz's severe judgment of post-conversion Steno was motivated by his resistance to the argumentative strategies deployed by Steno in intellectual exchanges with interlocutors such

as Spinoza and Sylvius—strategies he considered to be unjustified attacks on rational argumentation as such which testified to an intellectual attitude and conduct not aimed at the public good or the glory of God.

The second main section of the book is concerned with Steno's anatomical works and the complex relationship they bear to his refutation of Cartesianism. In the first contribution, Raphaële Andrault studies the relationships between the anatomy of the brain and the philosophy of mental functions, by focusing on the philosophical reception of the *Discours sur l'anatomie du cerveau* (particularly La Forge, Chapelain and Spinoza). According to her, the "critical experimentalism" adopted by Steno brought him to embrace a dualism between *res extensa* and *res inextensa* that paradoxically clashed with the Cartesian anthropology. A neglected manuscript from 1684 on sensorial stimuli and motor responses shows the connection between Steno's anatomical method of research and his metaphysical position on the seat of the soul.

Vasiliki Grigoropoulou takes a closer look at Steno's objections to the Cartesian brain anatomy in the *Discours sur l'anatomie du cerveau* and the responses to those objections given by Louis de La Forge, a Cartesian occasionalist who himself, earlier, had also replied to objections to Descartes put forward by Steno's mentor, Thomas Bartholin. La Forge's response to both Bartholin and Steno are of particular interest because he, contrary to Descartes, was a trained medical doctor capable of studying the role of the brain in mind-body relations on the same empirical level on which Bartholin and Steno discussed the role of the notorious pineal gland.

Taking his point of departure in the strained relationship between Steno and his senior colleague in Florence, Giovanni Alfonso Borelli, Troels Kardel focuses on Steno's work on muscles and muscle contraction in the *Elementorum myologiæ specimen seu musculi descriptio geometri*, published in 1667. He points out how Steno's work surpassed the anterior scientific tradition represented by Borelli. Stressing how Steno's myology aimed at providing an alternative to the Cartesian, mechanical, account of muscles, Kardel describes in detail how Steno's theory is constructed. In the second part of his paper, he studies the later reception of Steno's theory of muscle contraction, showing how early criticism was shaped by the reference to a basic Aristotelian axiom according to which all things in motion must be moved by something. Hence the famous Swiss mathematician Johann Bernoulli, following up on arguments first developed in Borelli's *De motu animalium*, argued that Steno's theory was absurd because it violated this philosophical assumption since it postulated movement without any influx of animal spirits. Kardel moreover shows how the subsequent reception of Steno's myology was haunted by a series of misunderstandings and misrepresentations of his position.

The third main section is dedicated to the philosophical implications and importance of Steno's work on the natural history of the Earth. Justin E.H. Smith's "Thinking from Traces" offers an interpretation of Steno's contributions to the methodology of geology, showing in particular how Steno, when inquiring into past processes, embraced a methodology that was later fully developed in Charles Lyell's *Principles of Geology* (1830–1833). It relied on the kind of inference that today, following Charles Sanders Pierce, is known as "abduction," which basically consists in inventing possible hypotheses (rules) to explain experimentally given data (results). In order to explain why, for Steno, abduction presented itself as an attractive form of inference, Smith turns to the philosophical commitments underlying his investigation into geomorphology. Arguing against the idea of a radical break between the early "scientific" and the late "Catholic" Steno, Smith notes that the post-conversion Steno's work on geology was the natural prolongation of a theological approach to natural philosophy that also characterized his earlier work.

Daniel Garber focuses on the relationship between Steno's work on the natural history of the Earth and Leibniz's famous *Protogaea*. In this work, Leibniz opposed the Cartesian account of the Earth's formation in favor of a geological history reconstructing the origin of fossils and the *facies terrae*, i.e. the stages in the evolution of the Earth's surface. Steno's *De solido intra solidum naturaliter contento dissertationis prodromus* has often been identified as one of Leibniz's main sources. Garber, however, shows that the influence of Steno on Leibniz is greater than has previously been suspected. Hence, on the basis of a Leibniz manuscript published, transcribed and translated in this volume for the first time, he provides compelling evidence that Leibniz came to his views not only through reading Steno's remarkable *Prodromus*, but also through personal conversations with the book's author in January 1678, when they were both present at the Court of Hanover. This is all the more remarkable in that it contradicts the common assumption that Steno abandoned all interest in scientific research and natural philosophy after 1677. It is, however, consistent with Andrault's article, which emphasizes that Steno also kept thinking about the brain and about muscles in 1684.

In the first contribution to the last section of the book, dedicated to Steno and his intellectual networks in Florence, Jakob Bek Thomsen shows the importance of the Medici Court and the influence of the so-called *Accademia del Cimento* on Steno's scientific method. He aims at demonstrating how the broader intellectual culture—a collaborative scientific culture—deeply shaped Steno's scientific work in the period, thus debunking certain popular myths about the originality and uniqueness of Steno as a seventeenth-century scientist. At the same time, Bek-Thomsen shows how the much-discussed question regard-

ing Steno's possible "membership" of the *Cimento* is misstated to the extent that the *Cimento* was not a formalized institutional structure, but rather a collaborative research project mounted around the publication of the *Saggi di naturali esperienze*. Thus understood, as a project rather than as an institution, Steno did take part in the *Cimento* and the experimentally based science animating that project influenced him profoundly. Hence, in *De solido*, he adopted a new "empirical" form of presentation which also characterized the *Saggi*, namely the so-called *historia* genre that focused on experience and on the accumulation of empirical data and rejected speculation about causes.

Frank Sobiech's chapter focuses on a neglected part of Steno's life: Steno's work as the preceptor of Ferdinando III de' Medici. Taking as a starting point Steno's unpublished papers from the *Biblioteca Nazionale Centrale di Firenze*, Sobiech shows how Steno's philosophy lessons for the crown prince were influenced by his experience as a natural researcher. From this it becomes clear that Steno did not stop thinking about the laws of nature, human freedom and the relationship between body and soul after his ordination in 1675. In particular, while annotating André Martin's *De anima bestiarum*, Steno stressed that animals have (mortal) souls.

In the final contribution to the book, Pina Totara mainly studies the path, from Florence to Rome, which led Steno to progressively abandon most of his scientific activities during his successive stays in Italy. She stresses in particular the incoherence of an otherwise popular notion according to which Steno successfully managed to reconcile science and religion. In fact, Steno's troubled intellectual itinerary in Italy exemplifies first of all the intellectual crisis surrounding Cartesianism. In Florence, Steno's anatomical studies, first conceived as a Cartesian research program, led him to repudiate the Cartesianism that originally inspired his work because of the irreconciliability of the Cartesian theory with empirical observation. Next, in a second phase associated with Rome, his eagerness to definitively distance himself from Spinoza, a former friend, further widened the gap between Steno and his own former self as a natural philosopher.

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PART 1

From Natural Philosophy to Theology

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CHAPTER 1

Modus politicus vivendi: Nicolaus Steno and the Dutch (Swammerdam, Spinoza and Other Friends), 1660–1664

Eric Jorink

1 Introduction

As is well known among Steno scholars, the Danish anatomist and theologian spent a crucial part of his life in the Dutch Republic.[1] As Scherz and others have pointed out, about half of Steno's scientific publications can be traced back to research carried out during his student years in Amsterdam and Leiden. Perhaps, as Steno himself occasionally mentioned after his conversion in 1666, the philosophical and spiritual atmosphere in the Dutch Republic was of even greater importance to his career. As he pointed out, in private correspondence as well as in his open letter to Spinoza from 1675, *Ad novam philosophiae reformatorem de vera philosophia*, his quest for salvation and eventual conversion to the one and only Church were encouraged or even prompted by the debates on religion and philosophy in the Republic. Originally coming from Lutheran Denmark, a country with a homogenous religious culture, and later converting to Roman Catholicism in Italy, which had an equally monolithic theological structure, Steno found the heterogeneous Dutch landscape of religious plurality and relative freedom of speech disturbing. According to himself, the road to his conversion was paved with encounters with Dutch philosophers and dissenters.[2] Hence, in a letter from 1672 to the Calvinist minister Johannes Sylvius, he described how during the "last years of my blindness'" (i.e. his stay in the Netherlands) the study of Cartesian philosophy, the prolific culture of religious disputes, and the "political way of living" (*modus vivendi politicus*) of the Dutch had weakened his ancient Lutheran faith, although he had not yet seen the true light.[3] In a letter to Leibniz from 1677, Steno described how he had lived in *ce*

1 I use the following additional abbreviations: ASF = *Archief Senaat en Faculteiten*, University Library Leiden; OBI = Borch, *Olai Borrichii Itinerarium 1660–1665*.

2 See Totaro, "'Ho certi amici in Ollandia': Stensen and Spinoza—science verso faith," pp. 27–38; Miniati, *Nicholas Steno's Challenge for Truth*, pp. 71–92.

3 Steno to Sylvius, 12 January 1672, in EP I, pp. 257–260, here p. 257.

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pays de liberté, "that country of freedom," a description that was not intended as a compliment![4] He described how, in Holland, "people practice their profession very freely and read all sorts of books."[5] While in the Netherlands, he had great esteem for Descartes' philosophy and for "all of those who were praised for their knowledge of that same philosophy."[6] In a very subtle way, God had, however, saved him from more "dangerous philosophers as well as from the politicians who loved the same kind of philosophy."[7] Here, of course, Steno primarily hinted at Benedictus Spinoza who had published his *Tractatus Theologico-politicus* anonymously early 1670 (in Amsterdam, although the fictive imprint indicated Hamburg) and whose *Opera posthuma* was about to be published, as Steno very well knew.[8] In his famous open letter to Spinoza of 1675, Steno already made it clear that he had met Spinoza during his student years in Leiden.[9] This is also clear from a letter discovered by Pina Totaro that Steno sent to the Congregation of the Holy Office on 4 September 1677, where he warned against the "evil and peril of propagation of this evil":

> About fifteen or sixteen year ago, when I studied at the University of Leiden in Holland, I had the occasion to become acquainted with the afore-mentioned Spinoza of Hebrew birth, but *of profession without any religion*, about whose doctrines I had only a confused understanding at the time [...]. And although in that period he paid me daily visits to see the anatomical investigations of the brain that I carried out on several animals in order to discover the place where motion begins and sensation ends, God nevertheless protected me so that he never explained to me any of his principles.[10]

4 Steno to Leibniz, November (?) 1677, in EP I, pp. 366–369.

5 Ibid.

6 Ibid.

7 Ibid.

8 See Spruit and Totaro, *The Vatican Manuscript of Spinoza's 'Ethica'*; Lærke, "*The Vatican Manuscript of Spinoza's* Ethica," pp. 843–847.

9 See Steno, *Ad novæ philosophiæ, reformatorem de vera philosophia epistola*, Florence 1675, transl. in Spinoza, *Collected Works*, pp. 929–935, esp. p. 930: "[...] I see shrouded in such darkness a man who was once my good friend, and even now, I hope, not unfriendly to me (for I am persuaded that the memory of our former close relationship still preserves a mutual love) [...]."

10 See Totaro and Spruit, "Introduction," in *The Vatican Manuscript*, pp. 9–10.

Whether Steno's understanding of Spinoza's ideas during his student years were in fact as superficial as he says will perhaps remain a mystery forever. This and other documents do, however, make it abundantly clear that Steno was very close to the epicenter of a circle of radical philosophers operating in the Dutch Republic, and that this made a decisive impact on his life and career.

Steno's contacts with Spinoza have attracted some scholarly attention. So have, albeit to a lesser extent, his relations with fellow student and lifelong friend Johannes Swammerdam and the minister Johannes Sylvius. Steno's early years in the Dutch Republic, however, have so far been somewhat neglected.[11] True, all biographical accounts mention his matriculation at the Amsterdam Athenaeum Illustre in April 1660, the discovery of the parotid duct in the house of Gerardus Blasius, and the subsequent priority dispute. They also describe how Steno moved to Leiden in July 1660, where he made some pioneering discoveries under the guidance of the professors Franciscus dele Boë Sylvius and Johannes van Horne. After moving back to Copenhagen in early 1664, Steno received his medical degree from Leiden University on 4 December of that year (*in absentia* and *cum laude*, which was quite extraordinary).[12] Moreover, we know that Steno spent some months in the Republic in 1670, when he engaged in both scientific endeavors and theological disputes. Finally, he visited Amsterdam some days in September 1674, trying to persuade his friend Swammerdam to embrace the Church of Rome.

Much more can be said, however, about Steno's meeting with the Dutch, their religious disputes and political way of living. While a more extensive account of the relations between Steno and his Dutch friends remains to be written—not only focusing on his exchange of ideas with Spinoza, Swammerdam and Sylvius, but also including those with other medical students (and converts) like Theodor Kerckring and Albert Burgh—I will here focus exclusively on his early years in the Republic from 1660 to 1664, i.e. the years preceding his conversion. This part of Steno's life has been the focus of speculation rather than than the object of fact-finding historical research—specifically about whether or not he was still a faithful Lutheran, whether he inclined to deism or even atheism, or whether he had already opened his heart to Catholicism.[13] On the basis of new documentary evidence, I will demonstrate how

11 For the most extensive accounts on Steno's first stay in the Dutch Republic, see Scherz, *Niels Stensen: Eine Biographie, vol. I: 1636–1677*, transl. in KM. See also Miniati, *Steno's Challenge for Truth*, pp. 71–92.

12 See P.C. Molhuysen (ed.), *Bronnen tot de geschiedenis der Leidsche universiteit*, Vol. III, p. 301*.

13 See Olden-Jørgensen, "Die Konversion Niels Steensen (1667) und der frühneuzeitliche

Steno, right from the first days of his stay in the province of Holland, was actively involved in a circle of rather unorthodox scholars and artists who all tended to value the quest for knowledge and the exchange of ideas higher than either their orthodoxy or their membership of a religious community. It was indeed religious plurality, lack of confessional boundaries, and relative freedom of thought and speech that characterized Dutch intellectual culture during this period.[14] Whereas, later in life, Steno would unambiguously distance himself from his earlier friends, I will show that, between 1660 and 1664, he actively participated in a network of physicians, artists, poets, alchemists, atheists and biblical critics—a network we have to look at more closely in order to understand his later aversion to the "political way of living" and his subsequent conversion.

2 The Blasius Connection

Steno decided travel to the Low Countries in 1660. He was obviously attracted by the new philosophy of René Descartes of which the Dutch Republic was the hotbed, and by the flourishing anatomical research, especially at Leiden University. The two images of Steno emerging, first, from the so-called "Chaos Manuscript" written in 1658–1659, and, later, from his period in the Netherlands in 1660–1664, form an interesting contrast. From the manuscript we can extract the portrait of a pious young scholar, living in seclusion and deeply immersed in both physics and metaphysics.[15] Steno in Holland, by contrast, comes through as a much less lofty student, assertively presenting himself to the world of learning. As soon as he settled in Amsterdam, in April 1660, the contemplative young man began to participate in the intellectual and social life of the bustling city, which by that time had become a hub of global trade and a flourishing center of the arts and sciences.[16] Steno is a very good example of how the Dutch Republic caught the attention of all Europe, attracting people to cities like Amsterdam, Leiden and Utrecht, to their universities, anatomical theatres, chambers of rhetoric, workshops, publishing houses, libraries and curiosity

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Deismus," pp. 108–110; F. Sobiech, *Herz, Gott, Kreuz*, p. 54; for a well-balanced discussion, see Miniati, *Steno's Challenge for Truth*, pp. 74–76.

14 See for example Israel, *The Dutch Republic*.

15 See Scherz (ed.), *Nicolaus Steno and his Indice*.

16 See Cook, *Matters of Exchange*; Van Berkel, "The Dutch Republic: Laboratory of the Scientific Revolution," pp. 340–367; Dupré and Lüthy (eds.), *Silent Messengers*; Jorink, "Undivided territory. 'Art' and 'Science' in the Early Modern Netherlands," pp. 6–33.

cabinets. One could give many other examples of curious visitors who stayed for a shorter or longer time, most famously René Descartes, but also Nicolas-Claude Fabri de Peiresc, Pierre Gassendi, Ole Worm, Ole Borch, Cosimo de Medici, John Locke and Gottfried Wilhelm Leibniz. The letters, diaries and travel accounts of travelers like these testify to the bustling intellectual and scientific activity in the Netherlands, as well as to the shortness of the lines of communication between persons and places. Moving from city to city by barge or by coach, such curious travelers witnessed anatomical dissections, performed chemical experiments, met religious dissenters, and visited printers' workshops.

Arriving in Amsterdam in April 1660, Steno took lodgings with the physician Gerardus Blasius who was about to be appointed professor at the Amsterdam Athenaeum Illustre—an institution that was not a fullblown university, but that did offer a propaedeutic course, the necessary requirement for studying in the higher faculties of theology, law and medicine in Leiden, Utrecht and elsewhere.[17] Steno's discovery of the parotic duct, and his subsequent priority dispute with Blasius, are too well known to be repeated here in detail. But it is relevant to us that Blasius lived at the Verwersgracht, which was not only close to the city's municipal hospital and the Athenaeum Illustre, but also only 400 meters away from the pharmacy De Star near the Montelbaanstoren where Johannes Swammerdam lived. And right in between these two locations were the Breestraat and the Jewish quarter where Spinoza was born.

It is tempting to think that these men might already have met during Steno's short stay in Amsterdam, but no documentation of any such early encounter exists. What we do know, however, is that young Steno actively and immediately sought to establish contacts within the city's scholarly elite. Steno's anatomy of the ray, written in 1664 and dedicated to Willem Piso, strongly suggests that the two met in in the summer of 1660.[18] Piso, famous for his research and book about the natural history of Brazil, was a key figure in the cultural world of Amsterdam in the 1650s and 1660s.[19] Trade, a love of knowledge as well as of the arts, collections of curiosities, and a strong interest in both religion and philosophy, including alchemy and millennarianism, went hand in hand—the travel accounts of Balthasar de Monconys, Christian Knorr von Rosenroth and Ole Borch, Steno's former teacher in Copenhagen and close

17 See Van Miert, *Humanism in an Age of Science*. On Blasius, see esp. pp. 290–300.

18 See Steno, *De musculis et glandulis observationum specimen*, pp. 48–70.

19 See Jorink, "Willem Piso (1611–1678)"; Bergvelt and Kistemaker (eds.), *De wereld binnen handbereik*.

friend, testify to this.[20] The ruling Amsterdam elite took a keen interest in the arts and sciences. One member of this elite was Johannes Hudde.[21] Trained at Leiden University in the 1650s, he was a brilliant mathematician and staunch defender of René Descartes. He was fascinated by optics and philosophy and would exchange knowledge and ideas with Christiaan Huygens and Benedictus de Spinoza. Hudde would later become one of the most powerful politicians of the Dutch Republic as, among other things, mayor of Amsterdam and director of the East India Trade Company (VOC). As such, he became an influential patron of the arts and sciences in his hometown, which could take pride in having a municipal theatre, the *Stadsschouwburg*, a *theatrum anatomicum* and a large number of curiosity cabinets, printers' workshops and private circles of poets, artists and scholars with surprisingly diverse religious backgrounds: besides members of the Reformed orthodox church, there were also Mennonites, Lutherans, a huge number of Roman Catholics (who were not allowed to practice their religion in public, but were tolerated to do so in private) as well as Jews, all kinds of sects such as the Quakers and Labadists, and a large number of people, such as the so-called collegiants, who did not belong to any of the established churches or religious denominations.[22]

Steno knew of all these things. His relations with Gerardus Blasius' younger brother Johannes are of great importance in this respect. Johannes, who was twelve years younger than Gerardus, was born in Leiden in 1639. He studied law and medicine in Utrecht, Leiden and Amsterdam. Earning a good living as a barrister, he also took great interest in the arts and sciences and became a key figure locally. At the Atheneum Illustre he defended academic disputations on medicine and law (the latter only two days after Steno defended his disputation on hot springs). The two men knew each other quite well. In a letter to Bartholin concerning the priority dispute with Gerardus, Steno mentions how Johannes Blaes "who lived in Amsterdam until May that year [1660] came to our home every day and attended all the dissections that were carried

20 See De Monconys, *Journal des voyages* (1665); Borch, *Olai Borrichii Itinerarium 1660–1665*; Fuchs and Breen, "Aus den Itinerarium des Christian Knorr von Rosenroth," pp. 201–256.

21 See Vermij, "Bijdrage tot de bio-bibliografie van Johannes Hudde," pp. 25–35; Vermij and Atzema, "*Specilla circularia*: an unknown work by Johannes Hudde," pp. 104–121.

22 An account of Amsterdam as a hub of knowledge where art, trade, science and religion intersected remains to be written. For important elements of the general picture, see Van der Wall, *De Mystieke Chiliast Petrus Serrarius (1600–1669) en Zijn Wereld*; Bergvelt and Kistemaker (eds.), *De wereld binnen handbereik*; Van Miert, *Atheneum Illustre*; Cook, *Matters of Exchange*; Jorink, *Reading the Book of Nature*.

out."[23] At the time Steno wrote to Bartholin, in November 1661, the peripatetic Johannes had, however, moved back to Leiden.[24] Now, Blasius kept an *album amicorum* which testifies to his interesting network and to his great mobility between Amsterdam and Leiden.[25] It provides a good example of how knowledge circulated between the two cities. Situated only 36 kilometers from each other (as the crow flies), the distance was easy to bridge, especially after a new barge service was established between the two cities in 1655. Many sources, including Borch's diary, testify to the lively traffic between Leiden and Amsterdam. When receiving news about some upcoming event in Amsterdam, Leiden students and professors would take the earliest barge north in the morning, attend the event, and then take the latest barge back home (or find lodgings), and vice versa. Cultural and intellectual life in Amsterdam and Leiden largely overlapped. Blasius' *album* testifies to this network: it was signed by professors from various universities and disciplines, by the Dutch *homo universalis* Constantijn Huygens (the father of Christiaan), by traveling scholars such as Matthias and Willum Worm, Ole Borch and Benedictus Skytte, and by many fellow students with whom Blasius would remain on friendly terms throughout his life. Blasius himself would play an important role in cultural life, publishing plays and poems, and became a regent of the Amsterdam *Stadsschouwburg* in 1670. Not surprisingly, as his album and other sources show, Blasius counted many artists among his friends, such as the libertine engraver Romeyn de Hooghe, and poets, including a surprising number of women. One of the latter was Catharina Questiers, a Roman Catholic playwright, engraver and collector of curiosities who signed Johannes' album on 17 May 1660, and to whom we will return later.

The album also bears witness to the great religious diversity in the Dutch Republic. Although the orthodox Reformed church was dominant, it never became a state church, much to its leaders' dismay. In fact, many politicians argued that the war against Spanish tyranny, which had begun in 1566 and officially ended only in 1648, had not been waged to facilitate new religious dogmatism. This more idealistic approach went hand in hand with a pragmatic one. In order to guarantee the reasonably peaceful coexistence of the various religious denominations and orientations, the regents usually favored a political approach to religious problems and tended to shun dogmatism or

23 Steno to Thomas Bartholinus, 20 November 1661, in EP I, pp. 144–146; here quoted after KM, p. 355.

24 He was already registered as a student on 26 February 1660 (see ASF 10, f. 570).

25 Heesakkers, "The Amsterdam professors and other friends of Johannes Blasius," pp. 179–232.

use of force. Only if religious and philosophical dissenters went too far and the pressure from orthodox ministers became too strong, the regents had to take measures, locally or nationally. Examples of this are the denunciations of Cartesian philosophy at Utrecht University in 1642 and the ban on Isaac la Peyrère's *Praeadamitae* issued immediately after its publication in Amsterdam in 1655.[26] In both instances, these were largely cosmetic measures taken by the political authorities, and intended to appease religious hardliners.

In this context, it is interesting to note that Blasius' album contains an entry written by Adriaan Koerbagh in 1662: "*Ad amico meo, in perpetua amicitia*."[27] Having been much neglected until recently, Koerbagh is recognized today as one of the key figures of the early Radical Enlightenment.[28] In the late 1660s, Koerbagh, a close friend of Spinoza, was an outspoken enemy of the power of the established churches and by far the Republic's most radical advocate of religious tolerance. Along with his brother Johannes, Koerbagh had studied in Utrecht and Leiden. He had obtained a doctorate in medicine in 1658 and a doctorate in law in 1661. Later, he settled as a barrister in Amsterdam, in the meantime also working on his increasingly radical ideas in close cooperation, it seems, with other radical thinkers such as Lodewijk Meijer and Jan Bouwmeester. In *A Light Shining in Dark Places*, the manuscript that prompted his arrest and subsequent prosecution in 1668, Koerbagh opened with the *a priori*: "The theologians preach hatred instead of love."[29] The theologians, Koerbagh continued, claimed to be the disciples of a savior who asked that "people should learn from him that he had a gentle, meek and humble heart." And yet, they taught mutual hatred, even among friends with differing opinions, and encouraged them to betray, ban, kill and burn each other.

> Oh what a difference this is, and that for no legitimate reason, but only a false accusation of unorthodoxy in the doctrine and worship of God. For none of the theologians, of whatever persuasion he may be, has so far properly set out, or been able to set out, a rational religion that does not

26 Van Bunge, *From Stevin to Spinoza*. See Van Bunge, "Censorship of philosophy in the seventeenth-century Dutch Republic," pp. 95–117; Israel, "The Banning of Spinoza's Works in the Dutch Republic (1670–1678)"; Israel, *The Dutch Republic*, pp. 677–699; Jorink, "'Horrible and Blasphemous'. Isaac la Peyrère, Isaac Vossius and the Emergence of Radical Biblical Criticism in the Dutch Republic," pp. 429–450.

27 University Library Amsterdam, Ms. V J 50 f x.

28 See for example Israel, *Radical Enlightenment*, pp. 185–196, and Van Bunge, "Introduction," in Koerbagh, *A Light Shining in Dark Places*, pp. 1–38.

29 Koerbagh, *A Light Shining in Dark Places*, p. 41.

> contain any articles that people need to force on each other to believe, the cause of which is the obscurity and confusion of Scripture, further increased by false interpretation and a false deduction of consequences. What is more, those theologians who accept the most rational and contradictory beliefs, worse even than pagan beliefs, are the only ones who are contaminated with all of the evils mentioned above, and they are the Roman Catholic priests. The other theologians, are all to some extent tainted with the first evil, namely hatred of one another, but all are also strongly dominated by pride and arrogance under the cloak of humility.[30]

A Light was only published in 1974 and demonstrates how Koerbagh considered religion on a purely rational basis, rejecting, for example, the concept of the Holy Trinity.[31] Koerbagh was notorious for his *Bloemhof* (1668) in which he had voiced similar thoughts and which had aroused the fury of reformed orthodoxy. Koerbagh had friends in high places, friends among the Amsterdam regents and burgomasters, such as Hudde. But pressure from the orthodox ministers became too strong after the publication of the *Bloemhof*. The Amsterdam sheriff Cornelis Witsen had Koerbagh arrested in July 1668. The manuscript of *A Light* had just been completed and was in press. All the printed sheets of *A Light* were confiscated and destroyed, except for two sets. After the trial, Koerbagh, who had confessed in the most general terms that he knew Spinoza and other freethinkers, was sentenced to forced labor, to which he succumbed in October 1669. Since he was moving in the same circles as Koerbagh in 1660–1664, Steno must have known him and it is tempting to assume that the Amsterdam physician and barrister was one of the "certain friends in Holland who made reason the judge of grace" Steno mentions when writing to Malpighi in 1671, only a few years after the Koerbagh trial.[32]

Back to 1660 and to Johannes Blasius. Steno is curiously absent from his *album amicorum*. This is not to say that they lost contact. It does not have anything to do with the upcoming priority dispute with Gerardus Blasius either, quite to the contrary. For on 26 February 1660, Johannes Blasius had once again matriculated as a student in Leiden and was, as we saw, moving back and forth

30 Ibid. p. 47, 49.

31 Koerbagh was arrested during the production process. Two copies of the remaining printed sheets and the manuscript survived. They have been transcribed and published in a rare Dutch edition by Vandebossche in 1974, available only in photo copy. A recent and much more sophisticated edition with English translation has been published by Michiel Wielema (see note 29 above).

32 Steno to Malpighi, 24 November 1671, in EP I, pp. 231–237.

between his city of birth and Amsterdam. Blasius continued to be registered in Leiden until 1663. When in Leiden, he stayed at the house of his mother, called *In de Halve Maen* ("In the half moon"), situated at the fashionable Steenschuur, the extension of the stately main canal Rapenburg.[33] This house was close to the Faliede Begijnenkerk, the confiscated church opposite the Academy building at the other side of the Rapenburg that after the establishment of the university in 1575 housed the anatomical theatre, the library and the fencing school.

On 27 July 1660, Steno matriculated at Leiden University. Scherz writes: "We do not know where he resided, perhaps in one of the *hospitia pro perigrinis* which [Holger] Jacobsen mentions."[34] The archives of Leiden University do however reveal a detail that has escaped previous Steno scholars, including Scherz. It can be found in the manuscript of the *album studiosorum*. Here, on 27 July, the rector noted that one Christianus Roudnicius from Bilthoven had matriculated as a student in medicine and was lodged by *"Mrs Blasius*."[35] The next line states that *"Nicolaus Stenonis, Danus, anno 23, medicus studiosus, habitat apud eandem*."[36] So, apparently, Steno rented a room from Johannes and Gerardus Blasius' mother. He lodged in the very same house where Johannes still occasionally stayed and were he also, as we know from other sources, occasionally received his friends.

This is more than a missing detail in Steno's biography. It is of course nice to know that he lived very close to the university building and the botanical gardens and even closer to the anatomical theatre. But knowing that Steno was a tenant of Gerardus and Johannes Blasius' mother also firmly links Steno to the lively network around Johannes Blasius. It is very likely that Johannes introduced Steno to all kinds of interesting people, like Koerbagh, kept him posted on upcoming events in Leiden, Amsterdam and beyond, and drew his attention to interesting visitors and the latest artistic and scientific publications. From Steno's letters, we know that he carried out private dissections at his lodgings, often in the company of others. It is also tempting to assume that the "daily visits" to Steno Spinoza paid around this time took place at the Blasius house.

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33 See ASF 32 "Recensio facto Anno MDCLXII" (no pagination, *sub* "Johannes"); and ASF 33 "Recensio facto Anno MDCLXIII" (no pagination, *sub* "Johannes").

34 Cit. in KM, p. 67.

35 For a partial transcription, see *Album studiosorum Academiae Lugduno Batavae MDLXXV–MDCCCLXXV*, The Hague: Martinus Nijhoff 1875. The original *alba* are kept at University Library Leiden and contain more details, including the place of residence of each new student.

36 ASF 10 f. 585.

We can recount yet more interesting facts about the Blasius household. From November 1660 onward, Ole Borch, one of Steno's former teachers in Copenhagen, was on a tour through Europe in the capacity as tutor to the Gersdorff brothers, but also to satisfy his own curiosity. During this tour, which lasted nearly five years, Borch kept an extremely detailed diary. After staying in Amsteram some months, where Steno paid him a visit, Borch matriculated at Leiden University on 21 February 1661.[37] From then on, Steno and Borch both studied medicine at Leiden. Schepelern, who has published a transcript of Borch's fascinating diary, notes: "Both Gustav Scherz and Johan Nordström have wondered why Borch so seldom mentions the name of Steno—'indeed almost avoids the name'—but this is no proof of any cooling down in their relationship."[38] Indeed not, for as the *album studiosorum* reveals, Borch also rented a room "op de Raepenborg *in de halve maen* by Juf. Blasius."[39] In other words, Steno and Borch lived in the same house. Here, in the stately house where both Gerardus and Johannes Blasius were raised, they would stay until February 1662. After that, both would move to Gualterus de Haes, custodian of the university library and printer of academic disputations, where they stayed for one year.[40] De Haes also lived close to the anatomical theatre. Even more than the Blasius house, this was a location that placed Steno and Borch close to the epicenter of Leiden academic life. Yet later, in February 1663, Borch and Steno took lodgings with one Dirck Swarts at an unknown location. Here, they would remain until the end of their stay in Leiden, which ended in mid-May 1663 and early 1664, respectively.[41] Thus, between February 1661 and May 1663, Steno and Borch were living under the same roof, very close to the Leiden hotspots of knowledge: the anatomical theatre, the academy building, and the houses of professors Sylvius and Van Horne (both living along the

37 *Album studiosorum Academiae Lugduno Batavae*, p. 486.

38 OBI I. p. xxxvii.

39 ASF 10 f. 601. The house does not exist anymore. It was destroyed by the explosion of a powder boat in 1807. From the descriptions—sometimes referring to the Steenschuur, sometimes to the Rapenburg—we may conclude that the Blasius house was very close to the anatomical theatre, which was situated at the point where the Rapenburg changes its name to Steenschuur.

40 See ASF 33: "Recensio facto Anno MDCLXII," no pagination (*sub* "Nicolaus" and "Olaus").

41 See ibid. and ASF 34, "Recensio facto Anno MDCLXIV," no pagination (*sub* "Nicolaus" and "Olaus.") The *recensio* took place every second week of February. Since Steno was re-inscribed in 1664 and was back in Copenhagen on 21/31 March, we can safely assume that he travelled back somewhere between mid-February and mid-March (see the account by Scherz in KM, p. 108).

Rapenburg canal) where they took private lessons and witnessed experiments and dissections. The implication of this is that Borch's diary between February 1661 and May 1663 to a great extent also reveals the day-to-day activities of Steno.

3 Leiden Students

On the basis of the Blasius album, the *album studiosorum*, Borch's diary and other sources, we can thus to a certain extent reconstruct the personal sphere and intellectual world in which Steno lived during his first stay in the Dutch Republic. Leiden University counted only fifteen professors in the period from 1661 to 1664. Four of those were in the faculty of medicine. Dele Boë Sylvius and Johannes van Horne were, by far, the most famous. During this period an average of 60 students matriculated in the faculty of medicine every year. The community was small and the lines of communication short.[42] Students crossed each other's path constantly: during class in the Academy building; when receiving instruction in the *hortus botanicus* and anatomical theatre; when following the daily bedside teaching of Dele Boë Sylvius in the municipal hospital; at disputations and other academic evenst. Borch's diary affords a fascinating glimpse into this intellectual microcosm. All students obviously knew each other quite well. Now, during Steno's and Borch's stay in Leiden, many other interesting students were registered, some of whom are well known to Steno scholars, others more obscure but of some relevance. Many among them had rather heterodox religious convictions and would later become radical thinkers. Koerbagh was one of them. Another significant example was Lodewijk Meijer who completed two doctorates at Leiden University, one on 18 March 1660 in philosophy and another in medicine, the very next day.[43] Besides being a close friend of both Spinoza and Koerbagh, and author of the notorious *Philosophia Sacrae Scripturae interpres* (1666), Meijer was a poet, a playwright, and a central figure of the cultural life of Amsterdam. Others, far from being militantly radical, adhered to the idea of an invisible church of all true Christians, belonging to those "Christians without church" famously described by Leszek Kolakowski.[44] Yet others, after initially adhering to het-

42 See Huisman, *The Finger of God. Anatomical Practice in 17th-Century Leiden*.

43 On Meijer, see Israel, *Radical Enlightenment*, pp. 197–207.

44 See Kolakowski, *Chréstiens sans Église*.

erodox ideas, would end up embracing the Church of Rome. In some cases, we have traces of direct contact with Steno.

Take for example the rather enigmatic Theodor Kerckring, who registered as a student on 12 May 1659.[45] Kerckring attended the Latin school of the art dealer and philosopher Franciscus van den Enden at the same time as the young Spinoza. Van den Enden has been considered the intellectual stepfather of the famous philosopher, although recent meticulous research by Frank Mertens has seriously called this into doubt.[46] Be this as it may, sources testify to the friendship between Kercking and Van den Enden, whose daughter he married in 1670. They also testify to the close ties between Kerckring and Spinoza. They shared a fascination for optics and anatomy, among other things. While studying in Leiden, Kerckring commuted between Amsterdam and his lodgings close to the Blasius family house at the fashionable Rapenburg.[47] It is unclear whether Kerckring ever obtained his medical degree, but he earned some fame as an anatomist, an alchemist and a collector of curiosities. Borch paid him a visit on 26 May 1662. We do not know whether Steno was present as well, but in any case he and Kerckring knew each other very well. Hence, in a 1680 letter to Steno, Kerckring would refer to their "*communia studiorum in Hollandia*."[48] Incidentally, Kerckring was yet another Lutheran friend of Spinoza to convert to the Church of Rome. In 1675, Kerckring moved to Hamburg. There, in the 1680s, he would frequent Steno yet again. Indeed, Kerckring housed Steno in his Hamburg *pallazo*, and Kerckring was appointed resident of Cosimo de Medici on the recommendation of Steno.[49]

From the Leiden *album studiosorum*, we also learn that on 22 February 1661, just one day after Ole Borch, Burchardus de Volder registered as a student in medicine.[50] Prior to that, like Steno, De Volder had attended courses at the Amsterdam Atheneum Illustre.[51] He was of Mennonite background and deeply fascinated by Descartes' new natural philosophy. De Volder earned his Leiden

45 See ASF 10 f. 544: "*apud Hubert Hermansz van Poelgeest op Rapenburg*."

46 See F. Mertens, *Van den Enden en Spinoza*.

47 Borch noted on 26 December 1660 that Theodor Kerckring lived "*op de Keisers-Gracht achter de Westerkerk*" (OBI I, p. 29).

48 Kerckring to Steno, 14/24 April 1681, EP II, p. 481.

49 See biography by Scherz in KM, p. 91. Little has been written about the relationship between Steno and Kerckring although the topic merits further exploration.

50 *Album studiosorum Academiae Lugduno Batavae*, p. 486.

51 See Van Miert, *Humanism in the Age of Science*, p. 390. On De Volder, see Wiesenfeldt, *Leerer Raum in Minervas Haus*.

medical degree on 3 July 1664. Although he certainly was no Spinozist, he discussed mathematical problems with Spinoza and Hudde on a regular basis in the mid–1660s.[52] In 1671, on the suggestion of the increasingly important Hudde, he was appointed professor of physics at Leiden University, on condition that he would convert to the Reformed Church. De Volder, who had collegiant affinities and was sympathetic to the concept of the invisible church, did this without hesitation. Like so many of his peer group—Adriaan Koerbagh being the most radical among them—De Volder was convinced that religious denominations and outward appearances were of far less importance than inner devotion. Although we have no direct evidence of this, Steno doubtless knew De Volder. Steno's laments about the Dutch "political way of living" could refer to incidents like De Volder's apparently completely unproblematic change of religion for the sake of a professorship: such a move appeared insincere and cynical to the outsider, but was perfectly sensible to a "Christian without church."

In this group of friends we also find Nicolaes Witsen, son of the merchant and Amsterdam burgomaster Cornelis Witsen.[53] Like his father, Witsen went on to become burgomaster of Amsterdam and one of the directors of the Dutch East Indian trading company. In this capacity, he had access to knowledge and to objects from all over the world, making him one of the most knowledgeable men of his days. He also became involved in the circles around the Royal Society in England and Melchisédec Thévenot in France.[54] Like Steno and De Volder, Witsen first attended the propaedeutic course at the Amsterdam Atheneum Illustre before matriculating at Leiden on 15 January 1663. He obtained a doctorate in Law on 11 July 1664. By that time, the ever-curious Borch had already paid him a visit in Amsterdam, during which the Dane was shown around in the city's impressive new town hall—the very same place where Cornelis Witsen in his capacity as sheriff would later charge Adriaan Koerbagh with heresy on 27 July 1668.[55] Witsen was on friendly terms with De Volder, Swammerdam and with Steno, with whom he exchanged information and books. Witsen and Steno shared a deep interest in geology. Witsen's book on shipbuilding, *Aeloude en hedendaegsche scheeps-bouw* of 1671, contains, besides entries by Hudde and De Volder, also information provided by his friend, "the famous and highly learned

52 Pieter Baert to Christiaan Huygens, 5 February 1676, http://ckcc.huygens.knaw.nl/epistolarium/ (consulted on 28 February 2016).

53 See Peters, *De wijze Koopman. Het wereldwijde netwerk van Nicolaas Witsen*.

54 Jorink, *Reading the Book of Nature*, pp. 326–333; Jorink, "In the Twilight Zone. Isaac Vossius and the Scientific Communities in France, England and the Dutch Republic," pp. 119–156.

55 Borch visited Witsen and the town hall on 29 July 1662 (see OBI II, p. 169).

man Nicolaes Stenonis."[56] Steno translated parts of Witsen's book from Dutch into Italian for the benefit of Vincenzio Viviani.[57] Among Steno's Dutch friends, Witsen was one of the few who adhered, and continued to adhere, to reformed orthodoxy. He had no more sympathy for heterodox protestant ideas than he had for the *propaganda fide* that Steno apparently sent him.

It was within this same student community that Steno became acquainted with Johannes Swammerdam. Unaccountably, as Miniati points out, "the relevance of this relationship seems to be quite undervalued by the most part of Steno's biographers."[58] The two would cooperate very intensely during their student days in Leiden and their subsequent stay in Paris. Later, they would keep each other informed about their respective research. Moreover, they were engaged in an ongoing discussion about philosophy and religion that continued until Swammerdam's premature death in 1680. To the extent, however, that Steno scholars have described their relation, it has been in terms that have often been slightly biased and not completely true to factual evidence. Scherz, for example, portrays Swammerdam too negatively:

> The great entomologist and one of the greatest zoologists of all time was of a deeply religious nature but so emotional that he would have needed clear guidance. However, with a certain stubbornness he resisted all attempts of Stensen to influence him. He was on the way to the visionary Antoinette Bourignon of whom he would blindly become a companion later.[59]

As we shall see, Swammerdam and Steno initially shared their intellectual framework and had similar religious and philosophical concerns.[60] However, when faced with the existential question about where to find salvation in a post-Cartesian world, they chose completely opposite solutions. For Steno it was in the Church of Rome; for Swammerdam—after a religious crisis where he seriously considered converting to Catholicism and had a short and disappointing stay in the community of Antoinette Bourignon in 1675–1676—it was in the invisible church of all believers. As he wrote in 1678 to Melchisédec

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56 Witsen, *Aeloude en hedendaegsche scheeps-bouw en bestier*, Appendix 14 b. Steno sent him am extract of a manuscript owned by Fransesco Gualdi.

57 Peters, *De wijze Koopman. Het wereldwijde netwerk van Nicolaas Witsen*, p. 50.

58 Miniati, *Steno's Challenge for Truth*, p. 95.

59 See biography by Scherz in KM, p. 251.

60 See also Jorink, *Reading the Book of Nature*, pp. 219–240; Jorink, "Outside God, there is Nothing," pp. 81–108.

Thévenot: "As for me, I am more Catholic than Reformed, but I do not despise anybody for that […]. [F]or only he who loves God and his neighbor like himself he may become blessed by Christ."[61] And God, Swammerdam maintained, was known *per excellence* through the study of the wonderful structure of His creatures. Swammerdam, after a short break in 1675–1676, would pick up his research where he had left it and dedicate himself to the study of God's great book of nature with renewed energy. Swammerdam was largely responsible for the increased attention that natural philosophers subsequently paid to the delicate structure of created things and thus also for the new emphasis on the "argument from design" that became so important in eighteenth century physico-theology.[62]

Swammerdam matriculated at Leiden University on 11 December 1661, only a year after Steno and more than half a year after Borch. Johannes Swammerdam was the oldest son of Jan Jacobsz Swammerdam, a wealthy pharmacist who owned an impressive collection of curiosities (Borch, and perhaps Steno, came to see it on 21 March 1662).[63] No register of matriculations of the Amsterdam Atheneum Illustre has survived, so no firm confirmation exists, but it is likely that Swammerdam attended propaedeutic courses at that school, just like his later friends Steno, De Volder and Witsen. It is equally unclear whether Swammerdam and Steno met during Steno's stay in Amsterdam from April to July 1660. Given the local intellectual geography, their roads probably crossed, but so far no piece of evidence has emerged. The first time Swammerdam is mentioned in a possible connection to Steno is on 28 November 1662, when Borch (in Steno's company?) paid Swammerdam a visit at his lodgings in Leiden to see his collection of *naturalia* and preparations.[64] Swammerdam rented a room from the printer Mattheys Severijn at the Pieterskerkhof, only a few yards from where Steno and Borch were lodged. In a letter to Thomas Bartholin from 5 March 1663, Steno described Swammerdam as a "very intelligent young

61 Swammerdam to Thévenot, January 1678, in Lindeboom (ed.), *The Letters of Jan Swammerdam to Melchisédec Thévenot*, p. 84.

62 It is a persistent but mistaken idea in scholarly studies that Swammerdam, after his stay in Bourignon's community, completely dropped scientific research. See for example Wilson, *The Invisible World*, pp. 88–90. The opposite is true: Swammerdam's best work, including the famous dissection of a louse, was done between 1676 and his premature death in 1680. See Jorink, *Reading the Book of Nature*, pp. 219–240.

63 See OBI II, p. 79.

64 See OBI II, p. 241.

man and very diligent in anatomical exercises."[65] They became close friends. Initially inspired by the Cartesian concept of nature and aided by their own talents as well as the fruitful Leiden academic setting, they would work together intensively for a couple of years. While Steno was eager to create an audience and to publish, Swammerdam was more interested in the material and visual tools of their research. It was, it seems, Swammerdam who introduced Steno (and Borch) to Hudde's new microscope and who stressed the importance of visual reports. For example, during Borch's first visit to Swammerdam he noted a drawing of a hermaphrodite that Van Horne had dissected a month earlier.[66] While Steno was soon to cast doubt on the value of Descartes' teachings in anatomical matters, Swammerdam would continue for much longer to conceive of the body as a piece of engineering. Likewise, Steno soon became disappointed in the iatromechanical framework promoted by Dele Boë Sylvius, a framework that Swammerdam only abandoned around 1670. Both Steno and Swammerdam, however, shared a deep conviction that studying the intricate fabric of anatomical structures was a tribute to God, the omniscient architect. But before we turn to a tentative analysis of the philosophical ground they shared, we first need to take a short look at some Amsterdam friends.

4 Friends in Amsterdam

As we have seen, the circles in Leiden and Amsterdam were largely overlapping. Distances were easy to bridge. Borch's diary illustrates the great mobility of the scholarly world. It also demonstrates Borch's interest in religion, philosophy, alchemy and, more generally, in unconventional or unorthodox people. It was quite often a Leiden contact who directed Borch's attention to an interesting person living in or operating from Amsterdam. We may safely assume that Steno was often informed about Borch's visits to these people, or was present himself. In 1660, on the same page where Borch noted where Theodor Kerckring lived, he also noted the address of Petrus Serrarius, "*op de Printzen gracht*."[67] Serrarius was at the center of a millenarian movement and, consequently, took great interest in alchemy, in the conversion of the Jews and, more generally, in the invisible church of all Christians. Inspired by the words of Daniel 12:4 ("But thou, O Daniel, shut up the words and seal the book, even

65 EP I, p. 168, quoted after KM, p. 442.

66 See OBI II, p. 241, and, on the previous dissection, p. 215.

67 OBI I, p. 29.

to the time of the end. Many shall run to and fro, and knowledge shall be increased"), Serrarius had entered into close contact with Samuel Hartlib's circle in England. The latter included natural philosophers such as Robert Boyle and Henry Oldenburg—the very same circle from which the Royal Society was about to emerge.[68] Borch visited Serrarius in July 1661 in the company of Steno.[69] Next, they visited the likeminded pansophist and millenarian Jan Amos Comenius. Borch was fascinated by the close ties between millenarianism and alchemy. The famous Johann Glauber, who had an impressive alchemical laboratory in the center of Amsterdam, was one of the first people Borch visited when arriving in the Dutch Republic and this was just the first in a long list of encounters.[70]

Borch, Swammerdam and their tutor Dele Boë Sylvius were much influenced by iatrochemical and iatromechanical approaches. As we saw, Steno kept much greater distance to this branch of knowledge. There was however one practitioner of this art who caught his attention, namely Catharina Questiers, already mentioned above.[71] Daughter of a wealthy blacksmith, she devoted her life to the arts and sciences. As a member of the circle around Johannes Blasius, she wrote poetry and plays, including some that were staged at the Amsterdam *Stadsschouwburg*, and illustrated them with etchings made by herself. She was a singer and a painter as well. Knowledgeable about handling metals and acids, she was also involved in alchemical experiments and owned a collection of curiosities. Questiers was well aware of her gender and insisted on her independence—a protofeminist trait found among other Dutch women of the time, most notably Anna Maria van Schuurman. Information about this rather remarkable woman can first be found in the entry in Borch's diary from 28 June 1661 when Johannes Blasius informed him about "*Cathrina Questiers viginem Amstelodemsem*."[72] After hearing more about her work and her collec-

68 See Van der Wall, *De Mystieke Chiliast Petrus Serrarius (1600–1669) en Zijn Wereld*, *passim*, esp. pp. 150–230.

69 See OBI I, p. 30. Borch later paid Serrarius another visit, on 18 September 1661. It is unclear whether Steno was present. They spoke, among other things, about antediluvian man and the apocalypse.

70 See OBI I–II, *passim*.

71 On Questiers, see Spies, "Catharina en de groten: over enkele illustraties van Catharina Questiers," pp. 597–614. On her contacts with Swammerdam, see Nordström, "Swammerdamiana. Excerpts from the travel journal of Olaus Borrichius and two letters from Swammerdam to Thévenot," pp. 21–65.

72 OBI I, p. 158.

tion, Borch took the barge from Leiden to Amsterdam to pay her an extensive visit on 20 March 1662. This was followed by a visit to the collection of Jan Jacobs Swammerdam—Johannes' father—the next day.[73] The following years, Borch stayed in indirect contact with Questiers, Swammerdam most often being the intermediary.[74]

Steno too became friends with Questiers. He actively participated in the Amsterdam circle around Blasius, Questiers, Vondel and others. Like others in the Blasius circle, including Joost van de Vondel, the famous Dutch poet, Questiers was Roman Catholic, a denomination that formed a hardly visible but important minority in Amsterdam. They occasionally discussed religion. Steno did not sign Blasius' *album amicorum*. He is, however, mentioned in a publication that documents the activities of the same group. On Blasius and Questiers' initiative, a volume of occasional poems, *Pallas Weefgetouw* (*Pallas' Loom*) was published in 1662.[75] It was a selfcelebrating collection of laudatory poems, puns, bridal songs etc. by the members of the Amsterdam circle. Among the contributors we find former students of Van den Enden, many female poets like Questiers, and Joost van den Vondel. And on page 149, we find an interesting poem by Catharina Questiers, addressed to "the learned man Nicolaus Stenonis":

> Wanneer de deught de weetenschap verselt;
> Soo slijt de tijdt vergeefs het menschen leeven
> Sijn naam hout stant al leyt hij neergevelt.
> Minerva heeft die in het staal geschreven.[76]
>
> When science is joined by virtue,
> Time does not affect a man's life.
> His name will stand, even if he is stricken down
> Minerva has written [his name] in steel.

73 See OBI II, pp. 78–79.

74 See Nordström, "Swammerdammiana," pp. 24–27.

75 *Pallas Weefgetouw, uytlevernde alderhand puyck-werken, van nieuwe sangh-vaersen, liersangen, punt- en verjaers-dichten, door d'edelste gheesten uyt-gewerckt*, Amsterdam; Bartholomeus Schouwers 1662.

76 Ibid. p. 149. This extremely rare volume—only one copy is known—was first studied by Mertens, *Van den Ende en Spinoza*. Questiers' poem was republished in *Lauwer-strijt tussen Catharina Questiers en Cornelia van der Veer. Met eenige by-gedichten aan en van haar geschreeven* (1665).

The Catholic virgin must have made an impression on Steno, although there is no trace of it in his surviving personal documents. Their relation may also be of some importance with regard to Steno's later conversion.

Besides documentation regarding the relationship, perhaps even friendship, between Questiers and Steno—who understood and presumably even spoke Dutch—we can extract yet more relevant information from the poem in *Pallas Weefgetouw*. The poem is introduced by the caption *"In het stamboeck van de geleerde heer Nicolaus Stenonis."*[77] This indicates that the poem now appearing in print had originally been written by hand in Steno's *stamboeck*, that is to say, his *album amicorum*. To the best of my knowledge, this is the first reference to the existence of any such personal document of Steno, and one wonders what happened to Steno's *album* and, most of all, who else signed it? Is this a source that may still one day turn up? Is it lost? Or perhaps destroyed on purpose? We shall leave such speculations for what they are. As Frank Mertens has pointed out, *Pallas Weefgetouw* and Blasius' *liber amoricum* are complementary sources, basically documenting the same circle of scholars and artists that, as we saw, both Borch and Steno knew very well.[78] Mertens convincingly shows how close the Blasius circle was to the network around Franciscus van den Enden and Benedictus Spinoza.

As has been noted by others, it was also during Borch's and Steno's stay in Leiden, on 17 May 1661 to be precise, that we find the first rumors on record regarding Spinoza.[79] Hence, in his entry on that date, Borch wrote that there were "some atheists in Amsterdam; most of them are Cartesians, among which there is an impudent atheist Jew."[80] Some months later, on 10 September, more information about Spinoza is recorded. Hence, Borch recounts how, in nearby Rijnsburg, a small village at a walking distance from Leiden where the collegiants had their meetings, "there lives somebody who had become a Christian from a Jew and now was nearly an atheist […]. [H]e occupies himself with the construction of telescopes and microscopes."[81] At some point during 1661, Spinoza had indeed moved to Rijnsburg. Henry Oldenburg visited him there, and we know from their correspondence that, at that time, Spinoza took great interest in natural philosophy in general, including alchemy and the work of Robert Boyle and René Descartes. This was also known to Borch, who, in a

77 *Pallas Weefgetouw*, p. 149.

78 See Mertens, *Van den Ende en Spinoza*.

79 See Klever, "Spinoza and van den Enden in Borch's Diary in 1661 and 1662," pp. 311–326; Klever, "Steno's Statements on Spinoza and Spinozism," pp. 303–316.

80 OBI I, p. 128.

81 OBI I, p. 214.

much quoted entry noted on 24 September 1661, wrote "that [Spinoza] excelled in Cartesian philosophy, what is more that he superseded Descartes, namely with his distinct and probable ideas."[82] Borch and Steno then met Spinoza, as Steno recollects it in his letter to the Holy Congregation from 1677:

> Once he [Spinoza] abandoned the rabbinical school of education, where he had studied for some time, he [began], thanks to his acquaintance with a certain van [den] Enden, suspected of atheism, and with the teachings of the philosophy of Descartes, to develop his own philosophy, in which he explained everything by matter only. [And] in that period he paid me daily visits to see the anatomical investigations of the brain that I carried out on several animals in order to discover the place where motion begins and sensation ends [...].[83]

I shall not address the much debated questions about how Spinoza became an expert in Cartesianism or what the exact date of his first encounter with Steno was. I only want to point to the fact that, around 1661 in Leiden, a group of men, all inspired by Descartes, where engaged in anatomical research with the aid of a new optical instrument, the microscope. Steno and Spinoza were among them, but there were others, most importantly Johannes Hudde. As we already know, Hudde had completed his medical degree in Leiden around 1655. He was mainly interested in mathematics, the new philosophy of nature of Descartes, and optics. Already in 1657 he wrote that he ambitioned "to begin, as soon as I have mastered the basics of medicine, to investigate by means of microscopes whether one cannot find and demonstrate *ad oculum* the generation of many things."[84] The Cartesian conception of the body as a machine encouraged research into the circulation of bodily fluids, respiration and the function of the brain, but also into the problem of procreation. If the body was a mere machine, where did baby machines come from? Hudde

82 OBI I, p. 228.

83 Cit. in Spruit and Totaro, "Introduction," p. 10.

84 Hudde to Velthuysen, 13 October 1657, University Library Amsterdam Ms. D 23, quoted in Vermij, "Instruments and the Making of a Philosopher: Spinoza's Career in Optics," p. 74: "[...] alzo ik van meening ben, zo haast als ik de fondamenten van de medicijnen zal geleert hebben, door vergrootglazen te onderzoeken, of men ad oculum de generatie van veel dingen niet zal konnen vinden en demonstreren; en hier toe zie ik door verscheyden experimenten, die ik alreede gedaan heb groote hoop, zulx ook dat ik bezigh ben de beste vergrootglazen te determineren [...]."

himself did not embark on this voyage of discovery. But he did provide the agenda as well as the necessary optical instruments. Hence, in the early 1660s, Hudde succeeded in manufacturing simple microscopes using drops of molten glass. Hudde generously shared his ideas and instruments with a circle of likeminded enthusiasts most of whom are now well known to us, including Witsen, De Volder, Swammerdam, Spinoza, the great scholar Isaac Vossius, and the painter Otto Marseus van Schrieck.[85] Although none of them explicitly mention it, it is tempting to assume that both Borch and Steno used the single-lens microscopes manufactured by Hudde. While Swammerdam mainly focused on the problem of procreation formulated by Hudde, Steno turned to the study of muscles and glands. Their interests, however, were overlapping and, as Borch, Steno and Swammerdam all relate, they often cooperated, for example in the field of comparative anatomy, dissecting all kinds of animals together (mostly Leiden stray dogs). In the next section of this paper, I shall turn to some tentative remarks about the intellectual ground they shared.

5 Swammerdam, Steno—and Spinoza?

As already noted above, the relationship between Swammerdam and Steno was of greater importance to both than most scholars so far have assumed, not only in scientific matters but also with regard to their respective philosophical and religious struggles. Whereas Steno's conversion has drawn considerable attention from many quarters, Swammerdam's spiritual crisis of 1673–1674, and his subsequent stay in Antoinette Bourignon's sect in Sleswick-Hollstein from September 1675 to April 1676, has been far less studied. Indeed, it has more frequently been the object of hearsay and misunderstanding than serious scholarship.[86] Swammerdam, it should be recalled, after studying in Leiden between 1661 and 1664, spent time with Borch and Steno in Paris. There,

85 On this network, see Jorink, "Outside God, there is Nothing," pp. 87–91; Jorink, "Beyond the Lines of Apelles. Johannes Swammerdam, Dutch Scientific Culture, and the Representation of Insect Anatomy," pp. 148–184; Jorink, "Snakes, Fungi and Insects. Otto Marseus van Schrieck, Johannes Swammerdam and Spontaneous Generation," pp. 196–233.

86 Almost all accounts go back to the biography Herman Boerhaave included in his edition of Swammerdam's *Biblia naturae* (1737–1738). It should be noted, however, that Boerhaave wrote more than half a century after Swammerdam's death. To the extent that I have been able to trace Boerhaave's sources, I must conclude that his account is not correct on all points and that it sometimes misinterprets or romanticizes sources. I am currently working on a new biography of Swammerdam.

he attended the conferences and enjoyed, together with Steno, the hospitality of Melchisédec Thévenot. However, when Steno, who had already obtained his medical degree, published several texts and increasingly caught the spotlights, moved to Italy late 1665, the less ambitious Swammerdam moved back to Amsterdam. Here, he joined the private circle of anatomists, the *Collegium privatum Amstelodamense* around Gerardus Blasius which, much in the spirit of the Academia del Cimento and the Royal Society, carried out collective research. He also became friends with Otto Marseus van Schrieck, the inventor of a unique genre of painting in which fungi, toads, snakes and insects were the main characters. Marseus had lived in Italy between 1650 and 1660 and had enjoyed—and continued to enjoy—the patronage of the Medici Court.[87] Incidentally, when Cosimo went on his trip to Northern Europe in 1667, the first painter he visited was Marseus. Apparently on Steno's advice, the prince also paid a visit to Johannes Swammerdam in the company of Thévenot.[88] At that time, Swammerdam was about to publish his *Historia generalis insectorum* (1669) in which he attacked the theory of spontaneous generation. In the following years, Swammerdam continued his research, now with a more intensive use of the microscope. At the same time, he became increasingly uncertain and anxious about his own activities: Rather than glorifying the biblical God's creation, was he in fact not just serving his own vanity? His religious crisis between 1673 and 1676 resulted from this anxiety.

According to the accounts of this crisis given by Scherz, Lindeboom and others, Swammerdam was nothing but a mentally unstable Calvinist who became ensnared by a hysterical mystic, Antoinette Bourignon.[89] A closer look at new sources however reveals that Swammerdam was not a registered member of the Reformed Church. He was rather sympathetic to the collegiants and other unorthodox movements.[90] Moreover, during his crisis, Swammerdam was not simply lured into the arms of a hysterical prophetess. For a long time, he doubted whether he could find salvation in the *imitatio Christi* advocated by Bourignon and Jacob Böhme, or whether he should turn to the Church of Rome as his good friend Steno recommended. In September 1674, Steno visited Swammerdam, bringing him a letter of invitation by Cosimo III.[91] Swammer-

87 See Jorink, "Snakes, Fungi and Insects," pp. 197–205.

88 See Jorink, *Reading the Book of Nature*, p. 229.

89 See Scherz in KM, p. 64; and Lindeboom (ed.), *The Letters of Jan Swammerdam to Melchisédec Thévenot*, pp. 14–30.

90 See Jorink, "Outside God, there is Nothing," pp. 102–105; M. de Baar, *'Ik moet spreken'. Het spiritueel leiderschap van Antoinette Bourignon (1616–1680)*, pp. 329–335.

91 Steno to Cosimo III, 25 September 1674, in NSE, I, p. 198.

dam came so close to accepting the offer to come to Tuscany, that Francesco Redi for a moment was convinced that Steno would take Swammerdam with him.[92]

The similarities between the developments in Steno's and Swammerdam's religious orientations are thus much more important than is usually acknowledged. Raised in Protestant environments and inspired by the prospects of Descartes' new philosophy of nature, they both began studying nature as a way to honor and glorify God, the creator of Heaven and Earth. The conviction that nature was Gods second book, open to all and useful for convincing non-believers of God's existence, was a cornerstone of Dutch Protestantism. As I have demonstrated elsewhere, this idea greatly influenced the study of nature in the Dutch Republic. Indeed, because of this, the study of nature became something of a religious duty, comparable to the close study of the Bible.[93] This conviction, codified in the Belgic Confession of 1569, was embraced by all denominations and created a common ground in the religious heterogeneous landscape of the Netherlands. It was in this context that Swammerdam and Steno worked as two deeply religious researchers who, initially inspired by the Cartesian notion of stable and uniform laws of nature, tried to observe and describe God's masterplan in even the tiniest of His creations. While studying in Leiden, they shared an intellectual context: they met the same people, and, as we know from various sources, often carried out dissections together. The language and concepts used by Steno and Swammerdam in this period are practically identical, revealing a deep and sincere admiration for God's work in creation, be it in a gland, a muscle, the structure of the eye or the anatomy of an insect. Their cooperation was complementary. Swammerdam was more inclined to iatrochemical research in the spirit of Dele Boë Sylvius and took greater interest in the problem of procreation; Steno was working in the down-to-earth empirical spirit of Van Horne. They both stressed the importance and value of images. Talented draftsmen, they included selfmade images in their publications (Steno sometimes also used images made by Swammerdam) and they both reflected theoretically on this issue.[94] Swammerdam drew upon the lively Dutch culture of painting, more specifically the genre of still life. He often cooperated with the painter Otto Marseus van Schrieck, who specialized in the representation of toads, fungi, snakes and insects and whose work was much in vogue in the 1660s. Although explicit references are lacking, it is tempting to

92 Ibid., note 8; De Baar, *'Ik moet spreken'*, p. 367.

93 See Jorink, *Reading the Book of Nature*, pp. 33–104.

94 Jorink, "Beyond the Lines of Apelles." See also Miniati, *Steno's Challenge*, esp. pp. 71–92.

suppose that Steno's use of images was also indebted to Dutch visual culture. In his use of images, like in so many other respects, Steno was an innovator, and the first two theses he defended a Leiden University included engravings. This was extremely unusual in this genre. Indeed, it seems to have been a novelty, and an expensive one at it, since having a drawing cut into copper was very costly.[95] Moreover, when the dissertations were published under the title *Anatomica de glandulis oris, &, nuper observatis prodeuntibus vasis* (Leiden 1661), Steno included an introduction in which he insisted on the gift of sight and on the importance of using images. The same theme reappears in his comments on the images found in the two editions of Descartes' *De l'homme* (1662 and 1664) and in his *Discours sur l'anatomie du cerveau* (published in 1669).

This brings me to my main point. Initially, both friends had great esteem for René Descartes. But Steno came to doubt the validity of Descartes' ideas at an early stage, as he also became convinced of the damaging implications of the Frenchmen's philosophy for anatomy as well for religion. It seems that Swammerdam remained attached to the new Cartesian philosophy much longer than Steno. He favored a far more positive reading and continued to refer to the notion of the book of nature as well as to Descartes when expressing his admiration for the divine architect who had made all creatures great and small. Moreover, Steno realized at quite an early stage that the God of Descartes and Spinoza, including the concept of fixed and immutable laws, made the role of Christ problematic if not superfluous. Swammerdam did not show signs of any discomfort before 1670. Be it a coincidence or not, this was also the year that the *Tractatus Theologico-politicus* was published. Swammerdam was not a Spinozist, quite to the contrary, but some of Spinoza's early ideas—as put forward in the *Korte Verhandeling*—may have encouraged him in his quest to search out the divine in the humblest of creatures. Around 1661, the move from considering God as the author of the book of nature to an outright identification of God with nature, might not have appeared so problematic. We know that, in 1661–1662, Steno became acquainted with Spinoza who was living in nearby Rijnsburg. No unambiguous evidence that Swammerdam ever met Spinoza has surfaced so far, but given the small size of the community, the shared friends and interests, it is highly unlikely that they were unaware of each

95 Most of the surviving theses defended in Leiden are at Leiden University and the British Library. To the best of my knowledge, the use of images in these and theses defended elsewhere in de Dutch Republic has not been studied. Having seen many of them, Dirk van Miert and I both conclude that Steno's dissertations are the first examples we know of.

other's existence. Steno's attitude toward Spinoza is well known. Swammerdam, on the contrary, was far less explicit and more ambiguous in his judgment. This had much to do with Swammerdam's changing ideas regarding the nature of God: at times, he envisioned Augustine's and Calvin's omnipotent Creator; at others, God was rather a Cartesian artificer and, on a few occasions, was identified with nature itself. Nature, according to both Swammerdam and Spinoza, was stable and uniform. One can here draw a striking parallel—which to my knowledge has not been noticed before—between Swammerdam's vigorous rejection of the theory of spontaneous generation (which according to him was not just empirically untenable but essentially blasphemous, since it presupposed contingency in God's eternal and perfect creation) and Spinoza's rejection of the biblical miracles in chapter VI of the *Tractatus Theologico-politicus*. Spinoza wrote:

> It is therefore far from being the case that miracles—understanding thereby something that contravenes the order of Nature—prove for us God's existence; on the contrary, they cast doubt on it, since but for them we could be absolutely certain of God's existence, in the assurance that all Nature follows a fixed and immutable order. [...] So if there were to occur in Nature anything that did not follow from her laws, this would necessarily be opposed to the order which God maintains eternally in Nature through her universal laws. So this would be contrary to Nature and Nature's laws, and consequently such a belief would cast doubt on everything, and would lead to atheism.[96]

My suggestion is that Steno and Swammerdam developed in similar ways, becoming aware of the religious implications of the study of nature in the spirit of Descartes and his radical offspring, but at different paces: Steno was faster in realizing the pernicious implications of especially Spinoza's ideas. Traditionally, nature had been seen as God's second revelation to mankind. Studying his creatures as carefully as possible was as important as Bible study and prayer. The ancient notion of the *liber naturae* gained new currency within the Cartesian context. If nature was a book, a work of art, or a machine, who else than a divine architect could be responsible for it? This was the heuristic *a priori* of both Steno and Swammerdam's work in the period between 1660 and 1664. The idea that God is manifest in nature is of course also a theme in Spinoza's early

96 Spinoza, *Tractatus Theologico-Politicus*, in *Complete Works*, pp. 447–448.

Korte verhandeling to which the two friends possibly had access.[97] This could have given them the idea that Spinoza was an ally. But if they knew the work, including the embryonic conception of the *Deus sive natura* it contains, Steno was much faster than Swammerdam in realizing its implications for the whole of Christianity, in particular with regard to the role of Christ and of salvation. What is the status of the Bible? What is the role of the redeemer? Where do we find salvation? After first rejecting Descartes on empirical and metaphysical grounds, and then presumably becoming increasingly alarmed by Spinoza and his circle, Steno eventually converted to the Church of Rome. Similarly, Swammerdam's much debated religious crisis of 1672–1676 in which the ideal of *imitatio Christi* was of extreme importance, could be read as a reaction to Spinoza's *Tractatus*. Swammerdam's work until 1670 had been intended to show God's greatness in the smallest of His creatures. But Christ was mentioned nowhere. During his subsequent religious crisis, Swammerdam increasingly struggled with the question of where to find salvation. He was struck by the idea of the imitation of Christ, considered the option of leaving the world behind, and began writing poems on the life of Christ (published as an appendix to a Jesuit work on the heart of Jesus engraved by Antwerp artist Antonius II Wierix).[98] In 1674, after pondering Steno's arguments and seriously considering converting to the Church of Rome, Swammerdam chose to follow the ideal championed by Antoinette Bourignon according to which one should become part of the invisible church of Christ. For her, salvation was rooted in the imitation of Christ and affinity with the invisible church, not in the adherence to any type of established denomination. This was a position that, in some respects, is comparable to Leibniz's conception of the love of God, which was also designed to address the problems of theological controversy.[99] Studying God in nature (or even identifying God with nature) and subscribing to the idea of God as the divine craftsman or architect, led to the question of where to find salvation. Steno would find it in the Church of Rome, Swammerdam would ultimately find it in the invisible church.

97 Jorink, "Outside God, there is Nothing".

98 De Baar, "Hartsemblematiek in Swammerdam's studie van de eendagsvlieg," pp. 312–334.

99 See Lærke, *infra*.

6 Epilogue: The Essence of Religion

"Mr Steno," Johannes Swammerdam wrote to Melchisédec Thévenot in January 1678, "is with the Duke of Hanover."[100] He told Thévenot that he had invited Steno to Amsterdam but that Steno declined, apparently held up by too many other affairs, and then went on to write a paragraph worth quoting here in full:

> I wish he were still like he was when he sought God in the bible of nature, then he would not be so opinionated in his religion and he would love all men, though they might not bear the name of his religion. As for me, I am more catholic than reformed, but I do not despise anybody for that and I would not like to change religion, for only he who loves God and his neighbors like himself, he may become blessed by Christ even if he were a Turk by birth, because we all have been saved by Christ, because God is trinity in person; and he baptized Cornelius with the Holy Spirit, before he even knew Christ. Therefor one should sacrifice to God all nations walking in ways of meekness and simplicity. *But Steno is all too partial, and he only thinks of making someone Catholic, without paying attention to the essence of religion*.[101]

This long quotation highlights both the common ground the friends once shared and the unbridgeable gap that now divided them. While studying in Leiden, the two men operated within comparable if not identical religious and philosophical frameworks. They drew from the same intellectual sources (certainly Descartes and probably also the embryonic ideas of Spinoza and his circle); they had the same friends (including Borch, Hudde, Witsen and Questiers); they were equally curious about God's great works of nature. Steno was more eager to dispute and publish, and established himself as a cutting edge anatomist much quicker than Swammerdam. Steno also preceded Swammerdam in detecting the inherent dangers of mechanical philosophy in relation to the issue of salvation. Descartes' work could be read as an endorsement of the traditional "argument from design," as Swammerdam did. However, facing both empirical evidence and metaphysical problems, both began to doubt their own religious position. While Steno and Swammerdam may have had comparable ideas about God and nature, their ideas on the essence of reli-

100 Swammerdam to Thévenot, January 1678, in Lindeboom (ed.), *The Letters of Jan Swammerdam to Melchisédec Thévenot Letters*, p. 198.

101 Ibid. (my italics).

gion and on the issue of salvation differed considerably. For Steno, it could only be found in the Church of Rome. As he, somewhat selfrighteously, wrote to Malpighi in 1675: "[Swammerdam] is searching for God, but he is not anchoring down in the Church of God."[102] Seen from this perspective, Steno could not, and never would, fully understand Swammerdam. In religious matters, he was essentially dogmatic and, as such, never capable of understanding or appreciating the Dutch "political way of living." Its curious mix of enlightened ideas and outright pragmatism seemed insincere and cynical to Steno. For Swammerdam, on the contrary, much a product of the religious diversity in the Low Countries where people had the liberty to philosophize and read all sorts of books, salvation was not to be found in the established tradition or in the power of one single church, but in inner devotion and in the invisible church of all true Christians.

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102 Steno to Malpighi, 18 July 1675, EP II, p. 306.

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CHAPTER 2

Jesuits, Women, Money or Natural Theology? Nicolas Steno's Conversion to Catholicism in 1667

Sebastian Olden-Jørgensen

1 Introduction

Nicolas Steno's conversion to the Catholic faith in 1667 has been the subject of much debate even if—or maybe because—he repeatedly explained his reasons for becoming a Catholic. This paper will present a variety of explanations, discuss the sources and explore the thesis that the key to understanding Steno's spiritual development is not to be found in traditional Catholic-Protestant controversial theology but in the deistic criticism of religion that he encountered among Dutch *politici* informed by natural law and Cartesian philosophy.

The views expressed in this paper were originally presented in a somewhat different form at a conference in 1998 and in an article in *Historisches Jahrbuch* (2001).[1] They have been further developed and corroborated by Frank Sobiech in his German dissertation (2004) which offers a comprehensive and systematic survey of Steno's spirituality including his conversion.[2] Steno's conversion has been further discussed by August Ziggelaar SJ in 2002 and by Ole Peter Grell in 2007.[3] I discuss their interpretations below. I will take account of these contributions to the ongoing discussion but mainly structure my analysis as a discussion of the key primary sources.

2 One Conversion and Three Explanations

On the evening of All Souls' Day, November 2, 1667, Nicolas Steno (1638–1686) had his religious breakthrough and decided that he would convert to

1 See Olden-Jørgensen, "Die Konversion Niels Steensens (1667) vor dem Hintergrund des frühmodernen Deismus," pp. 27–38; Olden-Jørgensen, "Die Konversion Niels Steensens (1667) und der frühneuzeitliche Deismus," pp. 97–114.

2 See Sobiech, *Herz, Gott, Kreuz*, pp. 39–68.

3 See Ziggelaar, "L'evoluzione spirituale de Niccolò Stenone giovane," pp. 77–83; Grell, "Between Anatomy and Religion," pp. 205–221.

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the Catholic faith. What really happened, and why, has been discussed ever since. Steno was by then already famous for his scientific work and cherished by friends for his personal integrity. His religious scruples had been no secret and news of his conversion soon entered the steady stream of information that flowed in the direction of Rome.

Towards the end of the same month the papal nuncio at Florence, Lorenzo Trotti, wrote about it to the Cardinal Secretary of State Decio Azzolino, i.e. to Pope Clement IX. Trotti told him how Steno over the previous 15 years (which is incorrect—five would have been more accurate) had investigated the doctrines of all the sects that had originated after the first four ecumenical councils (Nicaea 325 to Chalcedon 451) and eventually embraced the Catholic faith after having resolved his last doubts concerning transubstantiation, purgatory and papal authority. He added that "all has been brought to a happy conclusion thanks to the work and learning of the Jesuits but with such edification and drama that the conversion merited a separate account where one could see the loving artifice of the Holy Spirit in guiding to the truth him who had sought for it with such trouble, for so many years and with such moral rectitude."[4]

Around 1705, the Danish nobleman Christian Gersdorff (1644–1725) wrote a short autobiography in which he recounted having met his fellow student Nicolas Steno in Florence in the autumn of 1667 on his way back to Denmark after a long stay in Rome. They already knew each other from Leiden, where they had shared a room from 1661 to 1663. Steno arranged a private audience with Grand Duke Ferdinando II of Tuscany and Gersdorff was duly impressed, even when he wrote about it 40 years later. "Shortly before" this incident, Gersdorff writes, "Steno had gone over to the Papist camp, rather because of desperation than because of the preeminence of the Roman Catholic religion." According to Gersdorff, Steno had turned down favorable offers of academic positions from Leiden, Paris and Groningen in the hope of obtaining a similar position in Denmark. This hope had been frustrated—"maybe because of the hatred of one potter against the other" Gersdorff adds enigmatically—and Steno "not knowing what to do had obtained a stipend of 600 imperial dollars from Grand Duke Cosimo of Tuscany that the Pope had augmented to 2.000 after having noticed his religious fervor and given him the titular See of Titiopolis, which magnificent title he boasted of to the end of his life."[5]

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4 EP II, p. 925: "Tutto è felicemente riuscito con l'opera, e dottrina di questi PP. della Compagnia di Giesù, ma con tal'edificatione e varietà de'sucessi, che meriterebbe la conversione un distinto racconto, dove si vedesse l'artifio amoroso dello Spirito Santo nell'indrizzar alla verità chi con tale fatica, e tant'anni, e con morale bontà l'haveva indagata."

5 Royal Library Copenhagen, Manuscript Collection, shelf number: Ny Kongelig Samling 2010

In 1715, 48 years after Steno's conversion and 29 years after his death, C.N. Bambacari from Lucca published a biography of the saintly Mrs Lavinia Felice Cenami Arnolfini (1631–1710). According to father Bambacari, Mrs Arnolfini—being a good Catholic saint—had not only pursued her own personal sanctity but also inspired others to the path of perfection. According to Bambacari, it was her zeal that brought Steno to the Catholic faith and spurned him on so that he eventually became titular bishop and apostolic *nuncio* for the benefit of the heretical states of Germany and died in the odor of sanctity.[6]

What I have recounted above are three more or less contemporary and entirely reasonable accounts of Steno's conversion. They might be partly second hand—only one of the authors knew Steno personally and they all had their own agendas to pursue—but their explanations are as straightforward as one could wish for: Jesuits; money; a woman. However, they are also mutually contradictory and before making any judgments on the matter, it would be wise to also ask Steno himself.

3 Asking Steno

We are not the first to ask Steno this question. And in response he wrote three letters dealing with his conversion and also a long explanation of one of them: 1) a letter to Lavinia Arnolfini, wife to the Ambassador of Lucca in Florence (undated but probably around 1670, first published 1775); 2) a letter to the Calvinist pastor of the German church in Amsterdam, Johann Sylvius (dated 12 January, 1672, first published by Steno in 1677); 3) a letter to the German philosopher Gottfried Wilhelm Leibniz (probably November 1677, first

quarto: "Urbe postea egressum excepit Florentia Toscaniæ Metropolis, ubi ministerio Celeberrimi Nic. Stenonii Anatomici consummati, amici et in Belgio olim, Anglia et Gallia contubernalis ad colloquium admissus Magni Hetruriæ Ducis summam Heroici animi gravitatem pari commendabilem humanitate exosculatus est. Stenonius paulo ante in Pontificiorum castra transierat, desperatione potius inductus, quam Religionis Romano-Catholicæ præeminentia. Cum enim varias Parisienses, Lugdunenses, Groningenses vocationes ad summos in stadio Anatomico honores, in spem obtinendi in Patria paris muneris repudiasset /; quod tamen speratum tum temporis, ob odium forsan figuli in figulum, eventum non habuit:/ nescius, quo se verteret, stipendium meruit apud Summum Ducem Hetruriæ Cosmum de Medicis sexcentorum imperialium, quod summus Pontifex, perspecto Religionis fervore, 2000 Imperialibus annuis auxit, communicata insuper sede Episcopali Titiopolitana in partibus infidelium, quo titulo specioso ad ultimum vitæ terminum superbivit."

6 See Bambacari, *Descrizione Delle Azione, e Virtitù dell'illustrissima signora Lavinia Felice Cenami Arnolfini* (1715), pp. 36–39.

published 1952); and 4) the so-called *Defensio et plenior elucidatio epistolae de propria conversione* (published 1680) that further explained certain points from his letter to Sylvius.[7]

The letters and the *Defensio* afford us a lot of information. In spite of this abundant material, or rather because of its abundance, we do, however, run into new contradictions. For it represents very different perspectives on the same event. What are we to make of this, then? There are three strategies available. Either we try to combine all the sources into one picture on the assumption that they make up the pieces of a single puzzle. This harmonizing strategy was, more or less, the one chosen by the great Steno scholar Gustav Scherz (1895–1971). It inevitably leads to contradictions which, in Scherz's account, are glossed over in a somewhat lengthy treatment, but never really resolved.[8]

The second strategy is to settle for only one explanation, choosing according to one's general understanding of Steno, history and the world. If, for example, one subscribes to the psychological *cherchez la femme* principle there must be a woman behind Steno's conversion. The only question, then, is which one: Is it the ambassador's wife Lavinia Arnolfini as proposed by Bambacari, or the nun Maria Flavia del Nero, who wrote a somewhat ingenuous account of her role in Steno's conversion?[9] Or, as yet another option, was it an unknown young lady that Steno hoped to marry, as was suggested by Johannes Brunsmand (1637–1707), one of his later Protestant interlocutors?[10] Several older

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7 Letter to Lavinia Arnolfini first published in Fabroni (ed.), *Lettere inedite di uomini illustri*, vol. II, pp. 24–38. See also OT I, pp. 8–17; Letter to Johann Sylvius first published in N. Steno, *Ex pluribus as Ioahannem Sylvium Calvini dogmata Amstelodami docentem ante quinquennium & quod excedit scripsi, binæ Epistolæ, Altera de propria conversione, Altera de infelici ipsius Sylvii ad geminum propositum Syllogismum responso*, Florence: Giovanni Gugliantini 1677 [= *Opera theologica*, vol. I, pp. 121–129]; Letter to G.W. Leibniz first published in Steno, *Epistolae*, I, pp. 366–369 [= Leibniz, A II-1, pp. 576–578]. The explanation of his letter on his conversion was first published in N. Steno, *Defensio et plenior elucidatio epistolæ de propria conversione*, Hannover: Wolfgang Schwendimann 1680 [= OT I, pp. 371–437].

8 Scherz, *Niels Stensen. Eine Biographie*, vol. 1, pp. 191–213. See also the new, but somewhat haphazard, translation of the first volume of this biography in KM, pp. 185–202. See finally Steno, *Brief über meine Konversion*, pp. 9–31, and *Beatificationis et canonizationis servi Dei Nicolai Stenonis episcopi Titiopolitani (†1686) positio super introductione causae et super virtutibus*, pp. 60–63.

9 EP II, pp. 987–990. The account is dated 14 July 1688, addressed to a priest and evidently part of a systematic information gathering with a view to a possible canonization process. It was first printed in 1775.

10 OT I, p. 143.

Danish church historians and historians of medicine adhered to this principle: Jens Møller (1779–1833), Jørgen Wichfeld (1800–1888) and Julius Petersen (1840–1912). A variety of the same reading strategy can be found in the work of the historian of medicine Axel Hansen (1884–1945) and the theologian Knud Larsen (1895–1981). The latter two saw Steno as a modern style empirical scientist and, consequently, they believed that Steno reached his conclusions in the sphere of religion in the same way as he did in the sphere of natural science, that is to say, by generalization on the basis of observation and experiment.[11] The problem with this approach is not contradiction but naïve faith in the sources that support the chosen thesis and the arbitrary exclusion of the sources speaking against it. This is evident from the latest example of this strategy, namely a 2007 study by Ole Peter Grell dealing with Steno and his grand-nephew Jacob Winsløw (1669–1770), also an anatomist and convert to Catholicism. Grell criticizes all existing scholarship on Steno's conversion he knows of (including my own), "be it written by Catholic or non-Catholic scholars," for "its narrow focus on sources which reflect purely religious issues."[12] Instead of discussing Steno's own explanations and weighing the different testimonies against each other, Grell proposes a broader and more "cultural" explanation: According to him, Steno's conversion was due to his encounter with vibrant French Counter-Reformation Catholicism, personal contacts with the later famous bishop of Meaux, Jacques-Benigne Bossuet (1627–1704), and the influence of devout Catholic women in general.[13]

However, what initially seems like a refreshing new angle on Steno's conversion turns out to be flawed because cogent evidence for a "French connection" is missing. Steno, of course, discussed religious matters with people he met in France, but he did so everywhere else as well: in Germany, in the Netherlands and in Italy. He never singled out his stay in France as an especially important phase, but rather pointed to his years in the Netherlands and his friends in Italy. Last, but not least, Grell's evidence for personal contacts between Steno and Bossuet are tenuous to say the least. In all his theological works and letters, which comprise four folio volumes in the modern edition, Steno never once mentioned Bossuet. Grell's evidence for the connection consists of two references. One of them is to a book by Scherz that informs us that Bossuet profusely praised Steno. Scherz refers to a letter from 1732 by Steno's grand-nephew Jacob

11 Olden-Jørgensen, "Niels Steensens konversion bedømt fra dansk ikke-katolsk hold," pp. 77–93.

12 Grell, "Between Anatomy and Religion," p. 207.

13 Ibid., pp. 211–212.

Winsløw, one of Bossuet's many converts, who remarked that Bossuet "used to praise Steno and told me in particular that the prayers of this saintly bishop had contributed to my conversion."[14] This must refer to a time around 1700, because Winsløw converted in 1699 and Bossuet died in 1704. It might seem pedantic, but one must here observe that Bossuet's praise of Steno certainly documents high regard, but does not necessarily imply personal acquaintance.

Grell's second reference is to the English translation (1962) of the Italian Catholic author Rafaello Cioni's fluently written but rather fast-paced and literary Steno biography of 1953.[15] Cioni's biography is without references, but his claim presumably rests on a few lines in the first published biography of Steno, a seven and a half folio pages appendix to *Les vies des Saints pour chaque jour de l'année* (Paris 1722) by the French Jansenist printer Laurent Blondel (1671–1740). Blondel writes:

> Mr Steno thought that he would only know little if he did not go to France to study. He visited its principal universities but stayed especially long in Paris. There he fully found the profound learning he thirsted for. He became connected with the most capable persons in theology as well as in medicine and first and foremost with the knowledgeable Mr Bossuet, later bishop of Meaux.[16]

Laurent Blondel informs the reader that "he has made use of a manuscript given to him by Mr Winsløw [*on s'est servi d'un manuscrit qui a été communiqué par M. Vinslou*]," but there is every reason to be careful. The text is marred by numerous inaccuracies, its French bias is overwhelming and its general picture of Steno seems heavily colored by the author's Jansenist sympathies. There is a certain irony to the fact that Grell's vision of Steno's conversion ultimately reflects Blondel's attempt to claim Steno for French Jansenism. Until further

14 J.-B. Winsløw to Jacques Bénigne Bossuet, bishop of Troyes (nephew of the Jacques-Bénigne Bossuet, bishop of Meaux), 4 November 1732, in EP II, p. 994: "M^{r} Stenon […] dont feu M. de Meaux me parloit avec eloges me disant même en particulier que les prieres de ce Saint Eveque avoient attribué à ma conversion."

15 Cioni, *Niccolò Stenone. Scienziato e vescovo*, pp. 45–46.

16 Blondel, *Les vies des Saints pour chaque jour de l'année*, col. 1576: "Monsieur Stenon crut qu'il ne sauroit que peu de choses s'il n'alloit étudier en France. Il en visita les principales universités: mais il s'arrêta particulierement à Paris. Il y trouva avec plenitude cette science profonde dont il était alteré. Il s'y lia avec les personnes les plus habiles dans la theologie, aussi-bien que dans la médicine; & sur-tout avec le savant M. Bossuet depuis évêque de Meaux."

evidence is produced we will be well advised to follow the line of Gustav Scherz who in his definitive German Steno biography in two volumes (published posthumously 1987–1988) discussed the possibility of direct contacts between Steno and Bossuet only in order to rule them out.[17]

The third and last reading strategy, the one I favor myself, would be to evaluate the sources individually in relation to the questions at hand and attempt a reconstruction bearing in mind that the sources do not make up the total number of pieces of one puzzle, but rather represent selected pieces from several different puzzles. Whether that would imply harmonizing apparent discrepancies or choosing between mutually exclusive alternatives cannot be determined beforehand. It depends on the sources and the questions we want to answer. Sometimes we also have to conclude that some questions cannot be answered or only answered with much uncertainty. Let us take the three letters in turn.

4 Lavinia Arnolfini the Catholic

Steno's letter to Lavinia Arnolfini, wife to the ambassador of the city state Lucca at the court of the Grand Duke of Tuscany, is full of intriguing problems. It was published in 1775 by Angelo Fabroni in the second volume of his *Lettere inedite de uomini illustri* (Florence 1773–1775). The original no longer exists. Several other letters from Steno to Mrs Arnolfini are extant and they are all in French. The Italian text in Fabroni's *Lettere* is therefore most probably a translation. The letter is undated but written at a time when Steno served at the Medici court in Florence. That would cover the long period from 1666 to 1677, excepting a long geological research tour from 1668 to 1670 and his stay in Copenhagen as royal anatomist from 1672 to 1674.

The letter is a response to Mrs Arnolfini who had asked Steno to tell her why he had converted. This clearly presupposes that she did not know! And what is Steno's answer? He refuses to comply, arguing that his conversion was a theme for volumes rather than for a letter, thus implying that it was a complicated matter. In order to satisfy her partly, however, he instead addresses the Corpus Christi procession he witnessed in Livorno in 1666 where "God first prompted him to sincerely seek the truth that he has revealed to his Church and that one ought to believe with infallible, divine faith."[18] Catholic

17 Scherz, *Niels Stensen*, vol. I, pp. 136–137. See also KM, pp. 133–134.

18 OT I, p. 8.

commentators have been very enthusiastic about Steno's graphic description of how the example of intelligent and devout Catholics worshipping the Eucharist made an impression on him. They have been no less happy to make the central Catholic dogma of the transubstantiation the pivotal point of his conversion. In his analysis of Steno's spiritual development during his youth, August Ziggelaar constructs a beautiful continuity between a Corpus Christi procession Steno witnessed in Leuven during a trip to the Spanish Netherlands in the summer of 1663, a discussion about the Eucharist with the Danish nun Hedvig Margarete Elisabeth Ranzau and the Jesuit Jean de la Barre in Paris in 1664–1665, and the experience in Livorno in 1666. With reference to the procession in Leuven 1663 he rhetorically asks: "Is it possible that Steno remained untouched by this grandiose demonstration of the Catholic faith?"[19] A sober answer to the question would be: Yes, of course he could have remained untouched like so many thousand tourists then and later.

The wording of the letter to Lavinia deserves close attention. Steno does not tell her why he converted. Rather he pinpoints the exact moment when his religious search reached a new level of intensity and the Catholic Church became a serious alternative. We have to stress, however, that what he describes is the *beginning* of the process which eventually led him to the Catholic Church. It is not the reason for his conversion, not the turning point.

To complicate matters further, Steno is not consistent in his different accounts of when, exactly, he began to take religion seriously. According to this letter to Mrs Arnolfini, it was the summer of 1666. In a letter to Johann Sylvius (see below), however, it was as a result of a conversation with Mrs Arnolfini the following year. Finally, when, many years later, he told his chaplain Caspar Engelbert Schmael about his conversion, the decisive moment was pushed back in time. According to Schmael, who is our source, it happened when Steno was about 30 years old and he had a successful public disputation with a professor in Leiden. This became the first occasion for further investigating the truth, even if at that time he was convinced that all the mysteries of faith could be grasped by natural reason.[20] The account is somewhat confused, because the disputation in question must be the one with professor Blasius in Amsterdam and Steno was only about 25 years old at that time. Nonetheless, we now have three quite different occasions and moments for the conversion: a conflict with an academic senior in the Netherlands in the early 1660s, a Corpus

19 Scherz, *Niels Stensen*, vol. 1, pp. 195–196; Ziggelaar, "L'evoluzione spirituale di Niccolò Stenone Giovane," pp. 81–82.

20 EP II, p. 970.

Christi procession in Livorno in 1666, and a conversation with Mrs Arnolfini in Florence in 1667.

We know that Steno and Lavinia Arnolfini were very close. They corresponded to the end of his life and he called her his mother in Christ. This is strong evidence for her importance to him, but not conclusive in relation to the conversion. Furthermore, and this is most important, she had witnessed his conversion, but did not understand it and Steno was unable or unwilling to give her, of all people, a clear-cut answer.

5 Johann Sylvius the Calvinist

Steno's letter to the Calvinist Johann Sylvius, pastor at the German church in Amsterdam, dated January 12, 1672, is seemingly much more straightforward. It is part of a long exchange of letters that followed in the wake of religious conversations with old friends in the Netherlands at the beginning of 1670. It was published by Steno himself in 1677. In the letter, Steno once again underlines that he is unable to provide an exhaustive account, this time excusing himself by saying that the postal carriage will soon depart! He goes on to outline his religious development, enumerating the factors that gradually separated him from his protestant upbringing: (reluctant) religious conversations with Catholics; the religious pluralism of the Netherlands; the "political" lifestyle of many people in the Netherlands; dangerous Cartesian philosophy and the good moral example of Catholic friends.

However, he proceeds, the bustle of scientific work kept him from contemplating the religious question until "a noble lady" (surely Mrs Arnolfini) one day asked him whether he did not feel even a slight urge to become Catholic. Steno answered "no" because, as he said, even if he had observed much he liked among Catholics and much he disliked among Protestants, he had not seen anything that forced him to leave the religion that he was tied to through birth and fatherland. To this Mrs Arnolfini responded with an emotional plea, replying that she would readily shed her blood in order to convince him of the necessity to become Catholic. Impressed by this testimony of Christian love, Steno promised to give more heed to his own salvation. He began seriously to read works on church history, both Catholic and Protestant, but did not need to study much before finding good reasons for joining the Catholic Church. Nevertheless, he was paralyzed by so many "worries" and felt bound by "chains of darkness" until, on the evening of All Saints' Day, so many proofs and circumstances coincided that he had to acknowledge that God had taken him by the hand and led him to his church.

He goes on to mention the argument that made the greatest impression on him which is the argument of continuity or tradition: The Protestant churches can only point to arbitrary human reformers as their source of authority, whereas the Catholic Church builds on apostolic tradition. According to Steno, however, these arguments only afford "moral certainty" and are insufficient for a conversion. The necessary "divine certainty" is a matter of grace and has to be experienced in order to be understood.

One can point to a a number of interesting contrasts between the letter to Sylvius and the earlier letter to Arnolfini. Again, there is a watershed moment in Steno's spiritual journey. This time, however, it is not the Corpus Christi procession in Livorno (which is not mentioned at all), but a conversation with Mrs Arnolfini. If, however, this was indeed all true and Steno was prepared to say so in public, why did he not remind Mrs Lavinia of her crucial role in his letter to her? Moreover, the question of the Eucharist, as well as all other specific questions of controversial theology, are absent from Steno's account to Sylvius, which focuses on the general question of Catholic tradition and unity versus Protestant discontinuity and division. Last, but not least, Steno establishes a zone of silence around his final decision. He speaks vaguely and metaphorically of "worries" and "chains of darkness" and points to an overwhelming experience of God's grace as the real key to the whole process.

6 Leibniz the Lutheran

Finally, there is the letter to Gottfried Wilhelm Leibniz. The text is only known from the copy held in the Leibniz Archives. It is undated, but probably belongs to the early period of Steno's stay in Hannover. For this reason, Scherz dated it November 1677. The letter is a serious response to a witty or ironical question from Leibniz the previous evening, viz. whether Steno had found the Catholic truth in the marrow of bones. Steno could have answered Leibniz by simply pointing to his recently published letter to Sylvius, but did not even mention it. Instead he outlined a somewhat different spiritual path, stressing how his discovery of the anatomy of muscles, especially of the heart, had prevented him from being ensnared by Cartesian philosophy and had given him a healthy awareness of the frailty of the human spirit. From this he moves on to discussing religion, only to end up with the following alternative:

> Either every religion is good or only the Catholic religion is good; either religion is a law humans have invented in order to show due gratitude to their creator in which case it suffices to follow the laws of the country you

> live in; or God himself has prescribed us religion and then it must be one and in continuous existence from the creation of the world to its end. And of this last there is only one, viz. the one worshipping Jesus Christ in a community existing without interruption since the promises of his coming.[21]

Unable to decide which alternative to choose, he continued his travels and research, trusting God to show him which one was correct. Eventually he found himself in the bosom of the Church in a way he did not understand until he arrived there.

When comparing this letter to the other two, we again note significant similarities and no less significant dissimilarities. As in the letter to Sylvius, the argument of tradition is strong but not sufficient and Steno is unable to explain exactly what made him convert. Again, he relates a decisive experience, but this time it has nothing to do with the Catholic Church, but is located earlier in his biography and deals with anatomy and Cartesianism. He still takes up religious controversies, but the alternative he faces is not between Protestant and Catholic Christianity, but between any religion or religious community and Catholic Christianity. This is crucial, because it changes the context of Steno's conversion from a confessional setting and relocates it in the context of natural religion or rather deism and criticism of religion.

My thesis is that Steno had encountered and assimilated central tenets of a radical deistic subculture. In his letter to Sylvius, he refers to the Netherlands as the land of freedom and to the many people there living *more politico*. It seems many people did not quite understand what he meant by "living the political way" and in his *Defensio et plenior elucidatio epistolae de propria conversione* (Hanover 1680) he elaborates on this point. Here, he recounts how he knew several of these "political people" (*politici*) very well and that they ought to be called Hobbesians or Spinozists rather than Christians. More interesting than these derogatory epithets is Steno's summary of their religious standpoint.

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21 EP I, p. 368: "Et ammettant les discours particuliers des religions je me redusoit à la fin à cette proposition: Ou chaque religion est bonne, ou la seule catholique est bonne. C'est à dire: Ou la religion est une loix, que les hommes ont trouvé pour temoigner à leur auteur les obligations, qu'ils luy ont, et comme cela, il suffit de suivre les loix du pays, où l'on est; ou la religion nous est préscrite de Dieu même, et il n'y peut être qu'une seule, la quelle doit estre continuée depuis le principe du monde jusques â son fin, et de telle sorte il n'y a qu'une seule, à sçavoir celle, qu'adore Jesus Christ, où l'on a une societé continuée depuis les promesses de sa venue."

According to Steno, the political people believed that only two sorts of religion existed. The first one was for people who had given themselves up to the passions. These people were split up into different doctrines and it brought many evils upon themselves as well as upon others. The wording is calm and philosophical but what it means is that ordinary European Christians were irrational, sectarian, unhappy and intolerant. The second type of religion admitted by the political people were for those who governed themselves by reason and who let others have their way. They lived in peace with other people of all religions and temporarily adopted the outward observances of any religion. To them religion was nothing more than a bond of human society which they thought they alone understood but which everybody else simplemindedly held to be of divine origin.

What Steno here describes as the opinion of political people is identical with the first alternative outlined in the letter to Leibniz: "Either religion is a law humans have invented in order to show due gratitude to their creator, and then it suffices to follow the laws of the country you live in." That means that Steno had assimilated the concept of religion of these political people and subscribed to their criticism of religions in the sense that it represented the one of only two acceptable alternatives, at least if we are to trust his letter to Leibniz. For all that we know, their discussions were candid and in contrast to Arnolfini and Sylvius, Leibniz was a tolerant philosopher with a wide horizon that could encompass all sorts of religious doubts.

7 Deism?

But is this deism? What ought to be our yardstick?[22] I propose a very simple method: taking a look at Hugo Grotius' classic and immensely influential *De jure belli ac pacis libri tres* (1625), book two, chapter 20, paragraph 44 to 46. Here we find the concept of a "true religion" common to all ages and consisting of four short tenets: God is one; God is above the visible world; God cares about human affairs; God is the creator of all things except himself. This is the main content of paragraph 45. In the preceding paragraph, Grotius demonstrates the importance of religion in general, arguing that it not only gains us the grace of God but also is of great importance for human society. He then cites Plato to the effect that religion is a bulwark of authority and the laws as well as a bond

22 See Hudson, "Atheism and Deism Demythologized," pp. 13–23; Betts, *Early Deism in France*; Feil, *Religio*.

of good manners. And Plutarch is cited for the opinion that religion is a bond of every human society and a foundation of legislation.[23]

What we find in Grotius is a number of central principles that I think would also hold for Steno's deistic alternative to the Catholic faith: Religion as a necessary bond of human society in any age, a rational set of core beliefs including the demonstration of God's existence by means of the created world and a belief in providence. Moreover, Grotius' God of natural religion—like Steno's God in his famous prayer written down around 1665[24] but in contrast to many textbook definitions of Deism—cares about human beings.

I am not suggesting that Steno's political people were disciples of Grotius in the strict sense but only that Grotius was one important spiritual precursor. What lacks in Grotius—or is only present in the most implicit form—is the radical edge: Religion as *only* a bond of human society. Grotius would say *also*. And where Grotius focuses on the consent of all ages when establishing the central tenets of natural religion, the political people according to Steno made a sharp distinction between those who used their reason to understand religion and therefore practiced tolerance and dissimulation and those who were ruled by their passions and therefore harmed themselves and their fellow humans through their bigotry.

This edge and radicalism is of course found abundantly in Spinoza, but I do not find in Steno's political people many of the ideas that inform the *Tractatus Theologico-Politicus*. There is for example no trace of Spinoza's idea that religious worship ought to consist solely in the practice of justice and charity (*Tractatus*, chapter 14). Quite to the contrary: Grotius and the political people gladly accepted exterior forms of worship. Steno's political people seem

23 See Grotius, *De Jure Belli ac Pacis Libri tres* (1650), p. 340: "Religio autem quanquam per se ad conciliandam Dei gratiam valet, habet tamen & suos in societate humana effectus maximos. Neque enim immerito Plato religionem propugnaculum potestatis ac legum & honestæ disciplinæ vinculum vocat. Plutarchus similiter […] *coagulum omnis societatis & fundamentum*." This edition has been chosen as one Steno might have known. Actually *coagulum* is not "bond" but rather "rennet," i.e. the substance used for making cheese. Grotius thus uses a somewhat different metaphor which does, however, have the same meaning: Religion keeps society together.

24 OT I, p. 393: "Sine cujus nutu nec de capite capillus, nec de arbore folium, nec de aëre volucris cadit, nec menti cogitatio, nec linguae vox, nec manui actio excidit, tu conducisti me hactenus per vias mihi ignotas, conduc me per semitam gratae sive videntem, sive coecum; tibi facilius est eo me ducere, quo tu vis, quam mihi inde recedere, quo mea trahunt desideria." See also Olden-Jørgensen, "Die Spiritualität von Niels Stensen," pp. 15–25; Sobiech, *Herz, Gott, Kreuz*, pp. 327–335.

more influenced by stoic ideas of reason versus passion and hence by a staunch conviction to belong to the enlightened elite of men governed by reason and not to the multitude ruled by the passions.

On the question of Steno's deism opinions differ. August Ziggelaar thinks that Steno did not become a deist but only "remained in suspense" (*rimase in sospeso*) for several years. He has therefore argued, against myself, that if Steno, at the time, was a real deist, he would instantly have conformed to the religious culture of Italy and for example not have refused to pray the last part of "Hail Mary" that contains a prayer for Mary's intercession.[25] This argument is, however, not convincing. For, as long as Steno hoped for employment as professor of medicine in Copenhagen, there would be good deist reasons to refrain from adopting Catholicism. In any case, as long as no firm definition of deism exists, this might be a moot point. More important is the underlying reason for Ziggelaar's reticence: On the basis of some entirely conventional religious remarks in Steno's study notes (the so-called *Chaos Manuscipt*), he concludes that "Steno's Lutheran upbringing had surely contributed to make him capable of resisting the intellectual and moral temptations he met in the liberal Netherlands of that time."[26] Ziggelaar clearly subscribes to what could be termed a "continuity view" of Steno's spiritual development. This interpretation runs the risk of playing down the drama and seriousness of Steno's spiritual odyssey.

Frank Sobiech, however, has with good reason and ample documentation underlined the importance of Steno's deistic phase, which he furthermore subdivides into two distinct phases. During the first (1660–1662/63), Cartesianism and the political people shook his faith to the foundations. The radical nature of the situation explains why he later (1680) confessed to having been nearly seduced into atheism but brought back to faith in a creator God through anatomical dissection. In the second phase (1662/63–1667), he developed an ever-increasing confidence in divine providence.[27] This interpretation, partly based on unpublished source material (the remark on atheism), is entirely possible, even plausible, although it risks creating a little too much order in a process of which Steno himself could give no coherent account.

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25 See Ziggelaar, "L'evoluzione spirituale de Niccolò Stenone Giovane," p. 81.

26 Ibid., p. 80: "L'educazione luterana aveva contribuito certamente a rendere s capace di vincere le tentazioni, intelletuali e morali, che gli si presentavano nella liberale Olanda dell'epoca."

27 Sobiech, *Herz, Gott, Kreuz*, p. 61.

8 Discussion: Selection or Harmonization?

Steno provided three distinct accounts of the background of his conversion: One to a Catholic, one to a Calvinist and one to a philosophically minded Lutheran. Which account can we trust? How do we combine them? A quick answer to these questions would point to the fact that, evidently, Steno was unable to provide a simple answer himself. He told different stories at different times to different people, according to what he remembered and what he thought they could understand or needed to hear. After all, the only general claim in all three letters is that he really was unable to fully explain it. I think, however, we can say more. My hypothesis is that, contrary to what is generally recommended in historical criticism, we should build on the latest source, i.e. the letter to Leibniz, and make that our point of departure.

But why should we give priority to Steno's letter to Leibniz and not to the letter to his confidante Mrs Arnolfini or to his theological interlocutor Sylvius? I believe Steno did not tell the real story to Lavinia Arnolfini because he knew she would not understand. Even if she was a spiritual and educated lady she was probably ignorant of contemporary Dutch and French philosophy. What would she know about Cartesianism and political people? The Eucharist and controversial theology, however, she could relate to. So he told her about the Corpus Christi procession in Livorno and his studies of the Church Fathers.

What about Sylvius, then? He would probably know what Steno referred to when speaking of political people and Cartesianism. But he would have deplored it! If Steno had admitted to knowing such people and being impressed by their arguments, Sylvius would have been unable to continue to take Steno seriously. From a later letter, it becomes clear that the mere fact that Steno had once known Spinoza, "this dead God or rather monster," was incriminating in Sylvius' eyes.[28]

If, however, we accept my deism thesis, we can find further evidence of it in Steno's letter to Sylvius. As mentioned earlier, Steno there recounted how Mrs Arnolfini one day asked him whether he did not feel even a slight urge to become Catholic. It also indicates that she was much taken aback by his answer, namely that even though he had observed much he liked among Catholics and much he disliked among Protestants, he had not seen anything that forced him to leave the religion that he was wedded to by birth and fatherland. Steno's line of argument at this point actually chimes in quite well with the first alternative in his letter to Leibniz. If, basically, all religions are equally good ways of

28 OT I, p. 95.

honoring God, there would certainly be no reason to convert to Catholicism as long as he still hoped to obtain a position in Denmark. It is also quite significant that, in the letter to Sylvius as well as in the letter to Leibniz, Steno was unable to reach a decision by means of his own reasoning but described the decisive moment as an intense, but unexplainable or ineffable experience.

It is interesting that Steno never reduced the religious question exclusively to reasoning but reserved the decisive moment for grace. Here, one should not be deceived by the arguments Steno develops in the letter to Sylvius (Catholic virtue, tradition, Protestant disunity). Sylvius had asked for arguments and Steno responded accordingly. That, however, does not mean that any of those arguments were decisive for Steno. Steno clearly distinguished between moral certainty and divine certainty. For him, the arguments he advanced were sufficient to prove Protestants wrong. They were, however, insufficient to provide the divine certainty necessary for a conversion. This is something that, once again, corresponds well to the letter to Leibniz, in which Steno describes how, after much discussion, he became convinced that protestant Christianity was not an option, but that he still remained undecided between the claims of deism and Catholicism.

9 Conclusion

There are many simple possible answers to the question of the reasons for Steno's conversion to the Catholic faith. The most prominent among them refer to money, Jesuits, a women or a French culture shock. What all these answers have in common is that they disregard Steno's own explanations. This is clearly unacceptable unless one subscribes to the old protestant principle that honest and serious reasons for becoming a Catholic simply do not exist.[29] Steno, however, did not give any single clear answer. Instead, he presented us with a bewildering array of changing reasons, moments, persons and problems. Catholic and non-Catholic authors alike have attempted repeatedly to create some order in this confusion, each time reducing Steno's reasoning either to its Catholic or its scientific aspects, but without taking into account the utterances by Steno that fitted badly with their interpretation. In my discussion above, I have followed a third approach. On the one hand, we must admit that Steno's conversion was a truly religious and existential expe-

29 Nold, *Disputatio prior, contra Plur. Reverend. Dn. Nicolai Sthenonis Episcopi Titianopolitani, Scrutinium reformatorum*, f. A.

rience that he could not fully express and that changed aspect every time he thought and talked about it. This in no way impairs Steno's credibility. If he had quickly settled on a fixed narrative of conversion and stuck to it, our discussion of it might have been easier, but probably also less interesting! Keeping these reservations in mind, we may, however, advance a step beyond confusion. If the final reasons for Steno's conversion elude precise analysis, there are still good reasons for pointing to Dutch religious pluralism, deism and critique of religion as a fundamental and continuing challenge to his religious thought.

The implication of this analysis is that what happened on the evening of All Souls' Day was not a Danish Lutheran turning Catholic but a European deist finally returning to the Christian faith in the only form he could now take seriously, viz. that of the Catholic Church.

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CHAPTER 3

Leibniz and Steno, 1675–1680

Mogens Lærke

1 Introduction

The following section from Leibniz's philosophical bestseller, the 1710 *Essais de théodicée*, is doubtless his best known statement about Nicolas Steno:

> The good Steno, a Dane, who was titular Bishop of Titianopolis [*sic*], Vicar Apostolic (as they say) of Hanover and the region around, when there was a Duke Regent of his religion, told us that something of that kind had happened to him. He was a great anatomist and deeply versed in natural science; but he unfortunately gave up research therein, and from being a great physician he became a mediocre theologian. He would almost listen to nothing more about the marvels of nature, and an express order from the Pope *in virtute sanctae obedientiae* was needed to extract from him the observations Mr Thévenot asked of him. He told us then that what had greatly helped towards inducing him to place himself on the side of the Roman Church had been the voice of a lady in Florence, who had cried out to him from a window: 'Go not on the side where you are about to go, sir, go on the other side.' 'That voice struck me,' he told us, 'because I was just meditating upon religion.' This lady knew that he was seeking a man in the house where she was, and, when she saw him making his way to the other house, wished to point out where his friend's room was.[1]

This passage and the judgment it passes over Steno have contributed substantially to shaping the image of the Danish natural scientist and theologian among philosophers, from the early eighteenth century until today. The dominant picture is that of a superstitious fideist who rejected science under pretext of religion. The passage does however also suggest another, more positive image that comes more to the fore in other texts where Leibniz describes Steno as a disabused physician who rightfully turned his back on Cartesianism because his scientific experiments proved Descartes' natural philosophy

1 Leibniz, *Essais de Théodicée*, § 100, GP VI, p. 158.

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wrong. For example, in *De la philosophie cartésienne* written in the mid–1680s, Leibniz affirmed that "Mr Steno was disabused of Cartesianism when he discovered just how different the human body truly was from Descartes' man."[2] Hence, in Leibniz's mature texts—leaving here to one side Leibniz unmitigated admiration for Steno's *De solido intra solidum* (1669) and the role it played for his 1690 *Protogeae*[3]—the Danish intellectual appears Janus-faced, philosophically representing both an opponent and an ally. On the one hand, there was Steno the mediocre theologian, a paradigm of obtuse fideism and anti-scientific behavior. On the other hand, there was Steno the great anatomist, who was philosophically associated with Leibniz's own anti-Cartesianism.

In the following, I will trace the construction of this double image of Steno as a philosopher throughout Leibniz's texts in the late 1670s, with particular emphasis on the construction of the Steno as a "mediocre theologian." While we find scattered references to Steno in a number of texts written throughout most of Leibniz's career, his most substantial interaction with Steno and his philosophical work was concentrated around the second half of the 1670s (again leaving to one side his use of the *De solido intra solidum*). This was also the period during which Leibniz became personally acquainted with the Danish intellectual. The aim of this paper is to reconstruct this historical and biographical background for Leibniz's influential caricature of Steno in the *Essais de théodicée* and to determine to what extent that caricature was grounded in his personal impression of the man himself and his work.

2 Readings and Personal Encounters

The first time Steno's name appears in Leibniz's texts is in his 1671 treatise *Hypothesis physica nova*. It shows up, along with the names of Galileo, Torricelli, Fabri and Borelli, in a list of "very subtle" natural scientists.[4] The reference indicates no deeper knowledge of Steno's work. Leibniz's writings from this early period, when the young and upcoming natural philosopher still needed to

2 Leibniz, *De la philosophie cartésienne*, 1683–1685 (?), A VI, iv, p. 1486.

3 Leibniz to Philipp, 11 (21) March 1681, A II, i, p. 814: "Concerning my opinion of the works of Mister Steno and Mister Weigel: it must be granted that everything Steno has given us concerning physiology [*physique*] is excellent, but what merits most our esteem is the treatise he has written [entitled] *De solido intra solidum*." See also Leibniz to Thévenot, August 1691, A I, vii, p. 352; and Andrault, "Introduction," in Sténon, *Discours sur l'anatomie du cerveau*, pp. 11–12.

4 Leibniz, *Hypothesis physica nova*, 1670–1671 (?), A VI, ii, pp. 254–255.

make an impression on his senior peers, often included long lists of references and names, displays of erudition designed to impress his interlocutors. And the *Hypothesis physica nova* in particular was a work written with the express purpose of building his reputation. We should thus not deduce too much from this casual reference.

Next, in a fragment from 1 October 1675, hastily summarizing a conversation, Leibniz noted: "Mister Tschirnhaus tells me that Steno has written [...] to Spinoza, in order to persuade him of [the truth of] the roman [catholic] religion."[5] Leibniz here refers to Steno's open letter to Spinoza, published in Florence in 1675, the *Ad novam philosophiae reformatorem de vera philosophia*.[6] The person who had told him about this recently published pamphlet was Ehrenfried Walther von Tschirnhaus, a fairly close friend of Spinoza's who moved to Paris in the fall of 1675 and with whom Leibniz very rapidly became very good friends.[7] It is unclear whether Tschirnhaus knew about Steno and Spinoza's personal relations and, if he did, whether he told Leibniz about them. But it is significant that Leibniz first encountered Steno as a philosopher—as opposed to Steno the scientist—in the context of the latter's post-conversion anti-Spinozism. While Leibniz is most often presented, and rightly so, as a prominent anti-Spinozist,[8] his position on the matter at this early date, in 1675, was considerably more ambiguous than in his mature work. In 1675–1676, he discussed Spinoza's unpublished philosophy intensely with Tschirnhaus. The latter had brought a manuscript copy of Spinoza's *Ethics* with him to Paris and was, at the time, engaged in a deep correspondence with Spinoza about the latter's philosophy.[9] Leibniz listened in on these discussions and maybe he even

5 Leibniz, *Über ein Gesprâch mit Tschirnhaus*, 1 October 1675, A VI, iii, pp. 380–381.

6 See Steno, *Ad novœ philosophiœ, reformatorem de vera philosophia epistola* (1675), transl. as *A Letter to the Reformer of the New Philosophy, Concerning the True Philosophy*, in Spinoza, *Complete Works*, Letter 67A, pp. 929–935. On Steno's letter to Spinoza and their personal relationship, see Klever, "Steno's Statements on Spinoza and Spinozism," pp. 303–316; Totaro, "'Ho certi amici in Ollandia': Stensen and Spinoza—science verso faith," pp. 27–38; Miniati, *Nicholas Steno's Challenge for Truth*, pp. 163–178. For other recent work on Steno and Spinoza, see Andrault, *La vie selon la raison*, pp. 61–70, and pp. 308–312.

7 On the very complex relations between Leibniz, Tschirnhaus and Spinoza in 1675–1676, see Kulstad, "Leibniz, Spinoza and Tschirnhaus: *Metaphysics à Trois*, 1675–76," pp. 221–240, and Lærke, *Leibniz lecteur de Spinoza*, pp. 361–427.

8 For a complete survey of the relations between Leibniz and Spinoza, see Lærke, *Leibniz lecteur de Spinoza*.

9 The manuscript copy of the *Ethics* that Tschirnhaus brought to Paris is the same copy that he, for unknown reasons, in September 1677 in Rome, handed over to Steno. This is the so-called

participated in them via Tschirnhaus. Moreover, as is clear from Leibniz's philosophical fragments from this period, the so-called *De summa rerum* papers, he proved surprisingly well-disposed toward Spinoza's metaphysics—or rather toward what he heard about it from Tschirnhaus. There is thus good reason to think that, in 1675, Leibniz would have been less than sympathetic to Steno's onslaught on the "new reformer of philosophy," but there is no evidence that Leibniz read Steno's letter to Spinoza at that juncture.

It is not quite clear when exactly he did, but it was probably sometime during the first months of 1677. He refers to it in an eventually suppressed passage of an undated letter to Johann Friedrich from early 1677 in which he discusses Spinoza's response to a vicious missive sent by Albert Burgh, a former member of Spinoza's circle who, like Steno, had converted to Catholicism during a trip to Italy. Regarding Burgh's letter, Leibniz observes:

> Since I have not seen Mr Van der Burg's [letter], I know not what to say of it. But it seems, though, that his reasons [as also those put forward by Mr Steno in the letter he had written] are not very convincing. However, to state my opinion candidly, I am not satisfied with Spinoza's replies and objections either, even though he explains himself very neatly.[10]

Next, around March 1677, Leibniz wrote a fictive letter in which he went more into the details of Steno's refutation of Spinoza.[11] This letter confirmed the appreciation that was already apparent from the letter to Johann Friedrich: "I have the impression that Mr Steno presupposes too many things to persuade a man who believed in so few [...]. Spinoza would doubtless reply that those are all very pretty promises but that he has committed himself to believe nothing without proof."[12] Incidentally, the *Ad novam philosophiae reformatorem* was not the only polemical text by Steno that Leibniz read at the time. He also read and densely annotated a letter of controversy addressed to the Calvinist

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"Vatican manuscript" recently discovered and published by Leen Spruit and Pina Totaro (*The Vatican Manuscript of Spinoza's* Ethica, Brill: Leiden 2011). On this, see also M. Lærke, "*The Vatican Manuscript of Spinoza's* Ethica," in *British Journal for the History of Philosophy* 20:4 (2012), pp. 843–847; and M. Lærke, "A Conjecture about a Textual Mystery. Leibniz, Tschirnhaus and Spinoza's *Korte Verhandeling*," in *The Leibniz Review* 20 (2011), pp. 33–68.

10 Leibniz to Johann Friedrich, début 1677, A II, i, p. 467 (the passage in square brackets was subsequently struck out by Leibniz).

11 Leibniz, *Autre lettre au mesme* [*Zwei Fingierte Briefe*], March 1677 (?), A VI, iv, pp. 2197–2202.

12 Ibid. A VI, iv, p. 2198.

preacher Johannes Sylvius, published in Florence in 1675.[13] Leibniz composed yet another fictive letter with comments on this controversy.[14] I shall return to both fictive letters in some detail below.

But what prompted Leibniz to begin reading and commenting on Steno's work in early 1677? Let us return to the biography. In December 1676, Leibniz reluctantly went to Hanover to take up the position as court librarian that he had accepted in early 1675 after the death of his patron and employer, the Baron von Boineburg, and subsequent dismissal from his position as diplomatic envoy in Paris by the late Baron's wife. In comparison to the French capital, where Leibniz had discussed with the greatest minds of his time, the prospects for discussing science and philosophy at the rather provincial Hanoverian court were considerably less inspiring. For Leibniz, it was thus good news when—incidentally on the suggestion of Leibniz's own protector and correspondent, the Duke Johann Friedrich, a catholic convert—Steno was appointed Vicar Apostolic in Northern Europe, to be based in Hanover. Steno was not officially appointed to the position before August 1677, but given Leibniz's personal acquaintance with the Duke, he was very likely in the know regarding the plan long before. It may have been in preparation for this eventuality that he began reading some of Steno's philosophical work as early as January–March 1677.

Steno took his time before showing up. By the end of the summer, Leibniz was impatient to finally meet the physician-turned-theologian, as is clear from an August 1677 letter to his friend Hermann Conring.[15] In September, he announced Steno's imminent arrival in a letter to Jean Gallois.[16] The papal envoy finally arrived on 8 November. Shortly after, following one of their first encounters at a dinner at the Court where Steno had explained the motivations behind the radical change in his intellectual itinerary, he apparently felt that he should explain himself further and wrote Leibniz a letter to that effect: "[Our exchanges] have given me the desire to write down what can serve the glory of God and the salvation of those whom, via this same road of human presumption, would be lead to the precipice of this kind of [dangerous] philosophy."[17] This undated letter, written sometime in November 1677, is the only

13 See Leibniz, *Annotationes in Nicolai Stenonis Epistolam Secundam ad Johannem Sylvium*, January–March 1677, A VI, iv, pp. 2179–2188. For Steno, see *Nicolai Stenonis ad virum eruditum* (1675).

14 Leibniz, *Lettre à un ami* [*Zwei fingierte Briefe*], March 1677 (?), A VI, iv, pp. 2188–2197.

15 Leibniz à Hermann Conring, 24 August (3 September) 1677, A II, i, pp. 563–564.

16 Leibniz to Jean Gallois, September 1677, A II, i, p. 568.

17 Stensen to Leibniz, November 1677, A II, i, pp. 576–578, here p. 576.

existing correspondence between the two men. In it, Steno mainly explains his abandonment of scientific research by reference to a sense of humility and resistance to the presumptions of science: "And this, Sir, was how God, through anatomical discoveries, brought me to renounce upon philosophical presumption, and gradually prepared me to receive the love of Christian humility which, in truth, is the most dignified love that a reasonable soul is capable of."[18] As I explain below, the notion of "Christian humility" that Steno here promotes will prove crucial to Leibniz's overall assessment of Steno as a philosopher.

Late November, the two men had a long conversation about themes related to natural theology—including, among other things, the existence of God, free choice, absolute and hypothetical necessity, and divine foreknowledge.[19] While the account of this *conversatio cum Domino Episcopo Stenonio de libertate* subsequently written down by Leibniz was presented as simply reporting it, it is not always quite clear when Leibniz speaks in his own voice and when he reports statements made by Steno. Given Leibniz's fondness of fictive dialogues, it is also quite possible that some statements attributed to Steno are in fact statements that Leibniz invented on Steno's behalf. Putting these difficulties to one side, the text relates an exchange that prompted Leibniz to make some of his most poignant philosophical formulations from this period on key issues such as the principle of sufficient reason, hypothetical necessity, freedom as *spontaneitas rationalis*, and the authorship of sin. Seemingly, when writing down and elaborating further on the conversation with Steno, Leibniz felt that their exchanges had been fruitful.

That impression did not last. This brings me to the *Confessio philosophi*, a text originally written around late 1672–1673 mostly dedicated to the principles of divine creation.[20] It is occasionally referred to as Leibniz's "proto-Theodicy," since it introduces a number of themes that also figure prominently in the global argumentation of his *Essais de théodicée* some four decades later, including the notions of universal harmony, divine choice, and permissive will. There are, however, significant philosophical differences between the doctrine of creation Leibniz developed in the primitive version of the *Confessio philosophi* and the one found in the *Essais de théodicée*. These differences are

18 Ibid. p. 578.

19 Leibniz, *Conversatio cum Dominio Episcopo Stenonio de libertate*, A VI, iv, pp. 1375–1383, transl. in Leibniz, *Confessio philosophi. Papers Concerning the Problem of Evil*, pp. 112–131.

20 Leibniz, *Confessio philosophi*, ms. A, 1672–1673 / ms. B, end 1677 or early 1678, A VI, iii, pp. 115–149, transl. in Leibniz, *Confessio philosophi. Papers Concerning the Problem of Evil*, pp. 26–108.

of some importance, since Steno may unwittingly have contributed to the development of Leibniz's philosophical doctrine on this central point.

Most importantly, as has been stressed both by Paul Rateau and myself, there are elements in the young Leibniz's modal philosophy, in particular in his conception of the ontological status of pure possibilities, that brought him close to endorsing a doctrine not far removed from the kind of necessitarianism Leibniz later encountered in Spinoza's philosophy.[21] Leibniz wrote the *Confessio philosophi* late 1672 or early 1673. While it remained unpublished, Leibniz at that time felt that it was a sufficiently accomplished document to show to Antoine Arnauld in Paris.[22] Now, apart from the original manuscript, we have also a manuscript copy of the *Confessio* that includes a number of objections in the margins written in another hand than Leibniz's and accompanied by Leibniz's replies. As Otto Saame showed in his 1967 edition of the text, that other handwriting belongs to Steno. Hence, in late 1677 or early 1678, Leibniz showed the text to Steno, probably, as Yvon Belaval has suggested, as a follow-up to their November conversation concerning freedom. If, however, we study in detail the replies that Leibniz provided in response to Steno's inquiries, it becomes clear that those replies involve substantial revisions of the modal philosophy that Leibniz adopted in the first, primitive version of the manuscript from some five years earlier. Hence the considerable interest of those replies to Steno for Leibniz scholars.

Here, I will not account for Steno's objections and Leibniz's replies, but simply point to the following. While Leibniz indeed took Steno's objections as an occasion to revise some of his own previously held views under pretense of simply clarifying his position, it is nonetheless also the case that he had only moderate consideration for Steno's objections as such, finding them of little philosophical weight. Hence, while Leibniz responded at length to some of Steno's objections, many of them were also dismissed offhand as being beside the point, even ridiculous. Here is a selection of comments: "This is to quibble with the manifest intention of the author;" "I cannot imagine what my critic supposed while reading these things;" "this is a sign that my critic does not grasp my system well;" "this is an indication that my critic does not understand my system;" "my critic must have been in a hurry while reading the preceding;" "he does not understand;" "this is a ridiculous objection."[23] Leibniz was not

21 See Lærke, "*Quod non omnia possibilia ad existentiam perveniant*," pp. 1–30; Rateau, "La nécessité de l'*optimum* dans la *Confessio philosophi*: un nécessitarisme leibnizien?," pp. 163–174.

22 Leibniz, *Essais de théodicée*, 1710, GP VI, p. 43.

23 See Leibniz, *Confessio philosophi*, op. cit., notes L3, L20, L22, L26, L27, L30 and L31.

impressed. Indeed, there is good reason to think that, at this point, he had lost much faith in Steno's ability to engage in a productive discussion about the philosophical principles of natural theology, writing with dismay to Hermann Conring in January 1678:

> The man is moderate and, I think, good; he is, as I have come to learn, well-versed in anatomy and all things related to natural philosophy. It is however a kind of study that I am sad to say that he is now most adverse to, for far from being an obstacle to piety, it provides, on the contrary, a constant motive for praising God.[24]

There is, however, as Daniel Garber shows in his contribution to this volume, some evidence that Leibniz eventually did manage to engage Steno in discussion regarding the *De solido intra solidum*. Hence, in a 1681 letter to Christian Philipp, after praising Steno's little work on geology, Leibniz's claims that he had "often urged him to go further, and to derive the consequences of it for the origins of mankind, the general deluge, and some other beautiful truths that confirm what is said of it in the Sacred Scriptures."[25] And yet again, in the *Protogaea*, while discussing Steno's theory of geological sediments, Leibniz writes that "I remember hearing him tell us about this often, and that he rejoiced in contributing, through natural arguments, and not without benefit for piety, to a belief in the sacred history and the universal flood."[26] If to anything, these statements must refer to personal exchanges at the Court of Hanover in 1677–1680.[27]

Finally, we should mention an intriguing, even troubling, letter that Leibniz wrote to Landgraf Ernst in 1680:

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24 Leibniz to Conring, 3 (13) janvier 1678, A II, i, p. 579 (I am grateful to P. Rateau for his help in translation of this passage). See also Leibniz to Conring, 19 (29) March 1678, A II, i, p. 598. Note, however that, in June 1679, only a few months after venting his disappointment to Conring, he wrote to Jacques-Bénigne Bossuet: "We now have here Mr Steno, Bishop of Titianopolis, already well-known from the past for his discoveries in anatomy. Now he applies himself to controversy, where he shows great judgment and moderation" (A I, ii, p. 482). Given the recipient of the letter, there is room for doubting the sincerity of Leibniz's praise here.

25 Leibniz to Christian Philipp, 11 (21) March 1681, A II, i, p. 814.

26 Leibniz, *Protogaea*, p. 19.

27 See Garber, *infra*.

> Mr Steno has left Hanover and gone to Münster where he will occupy a position as *suffragan*, or *Meihbischoff*. We have not urged him to leave, but on the contrary treated him with much civility. It is a person of merit who has great erudition, zeal and integrity. It seemed to me, however, that he sometimes values little details over the essential. For example, he would rather approve certain equivocations that may cause some harm than [allow] completely innocent lies; whereas I thought exactly the contrary.[28]

While this text does not exactly praise Steno, it does however suggest another, more subtle image of Steno's character than that of an anti-scientific fideist. It is not quite clear whether the final phrase regarding equivocations and lying suggests that Leibniz initially thought that Steno believed the contrary, thus here clearing Steno of a previous suspicion of endorsing innocent lying, or whether Leibniz objects to Steno's position, thus himself endorsing the use of innocent lies. The somewhat ambiguous opinion that Leibniz elsewhere expresses regarding the permissibility of lying does, however, speak in favor of the second interpretation.[29]

After Steno's departure for Münster in 1680, there were no subsequent direct exchanges between the two men. But Leibniz provided an interesting epilogue to their personal encounter when writing a fictive dialogue in mid-1679, the *Dialogue entre Poliandre et Theophile*.[30] The text stages an encounter between Poliandre, "an apostolic missionary" and Théophile, "a very cultivated man of the Augsburg confession." It is generally acknowledged that Poliandre and Theophile are proxies for Steno and Leibniz, although these identifications should be handled with some caution. As is the case with other, similar dialogues from the same period, Leibniz's fictive versions of his real interlocutors were in some respects deliberately different from their models.[31] As I will

28 Leibniz to Ernst von Hessen-Rheinfels, 17/27 October 1680, A I, iii, p. 246.

29 On this, see Leibniz, *Mendacium falsiloquium non damnatum*, [undated], in G.W. Leibniz, *Textes inédits*, p. 702 (partial edition). For an English translation of the complete text, see Leibniz, *The Art of Controveries*, pp. 148–152. For a brief discussion, see Lærke, *Les Lumières de Leibniz*, pp. 86–87.

30 Leibniz, *Dialogue entre Poliandre et Theophile*, mid–1679 (?), A VI, iv, pp. 2219–2227. For another study, see Vad, "Polidore and Théophile: The Rationalist and the Faithful Observer," pp. 39–47.

31 See for example Leibniz, *Conversation du Marquis de Pianese et du Père Emery Eremite*, 1679–1681 (?), A VI, iv, pp. 2245–2283. As I have shown elsewhere, the "Father Emery" of

show below, we thus occasionally see distinctly Leibnizian theses attributed to Poliandre. Moreover, the dialogue unfolds as a process where Steno-Poliandre's staunchly Roman Catholic way of thinking is gradually modified and inflected towards Leibniz–Theophile's more ecumenical and rationalistic mindset.

If we are to understand the exact motivations behind the mature Leibniz's attitude toward Steno as a philosopher, I believe we must search them out in these texts from the late 1670s when he engaged personally and deeply with Steno himself. And the fact of the matter is that, while Leibniz's admiration for Steno's work in anatomy and paleontology never faded, he was first and foremost deeply disappointed in the person he encountered in Hanover. There are three systematic reasons for that disappointment that I shall now consider one by one.

3 Leibniz on Steno as a Controversialist

The first reason concerned the way Steno behaved in his exchanges with other theologians and philosophers. Leibniz formed his opinion about Steno's intellectual conduct mainly from reading Steno's polemical letters to Spinoza and Sylvius, but presumably also from his own exchanges with the man, in particular in relation to the *Confessio philosophi*.

As already noted above, in his 1677 comments on Steno's *Ad novam philosophiae reformatorem*, Leibniz was quick to note the futility of Steno's attempt at converting Spinoza who was less than likely to yield to the traditional arguments of a Roman Catholic controversialist. Leibniz did not, however, stop at this. Given that Spinoza never himself replied to Steno (indeed probably never read the letter), Leibniz also undertook to respond in detail on Spinoza's behalf: "I do not know what M. Spinoza might have replied, but for me I say candidly what I would have responded if it was up to me."[32] Leibniz stressed, among other things, that "often hypocrisy and ambition deform sanctity," that "all the sects have people whose life has been strict and irreproachable" and, most importantly, that "true perfection does not consist in what a great many people imagine, but in the perfection of the understanding and in the empire over the senses, things that are as rare in the Roman [Catholic] Church as elsewhere."[33]

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that conversation is an "improved" version of the French erudite Pierre-Daniel Huet (see Lærke, *Les Lumières de Leibniz*, pp. 198–204).

32 Leibniz, *Autre lettre au mesme*, A VI, iv, pp. 2199–2200.

33 Ibid., A VI, iv, p. 2200.

It is worth noting that many of the points Leibniz advanced were in fact also made by Spinoza himself in his reply to Albert Burgh, a letter from Spinoza that Leibniz also read at this time, in early 1677, and commented on in a letter to Johann Friedrich.[34] Indeed, to Leibniz, and not without justification, there was little difference between Steno's and Burgh's positions and he considered Spinoza's reply to Burgh a perfectly valid response to Steno as well. So how did Spinoza reply to Burgh?

The exchange is famous. In his long letter to Spinoza, littered with insults and scarce in argumentation, Burgh advanced as his principal point the following:

> You claim to have finally discovered the true philosophy. How do you know that your philosophy is the best out of all those that have ever been taught in this world, are at presently being taught, or will ever be taught in the future?[35]

Spinoza's reply was a paradigmatic expression of the geometrical mindset animating the Cartesian branch of modern philosophy:

> I do not presume that I have found the best philosophy, but I know that I understand the true one. If you ask me how I know this, I reply that I know it in the same way that you know that the three angles of a triangle are equal to two right angles. That this suffices no one will deny who has a sound brain [...]. For truth reveals both itself and the false.[36]

In his 1677 comments on Spinoza's reply to Burgh, Leibniz's reaction was a surprisingly unequivocal and forceful endorsement of the Dutch Jew's reply:

> What [Spinoza] says about the certitude of philosophy and demonstration is good and incontestable; and I admit that those who always ask us: 'How do you know you are not mistaken since so many others have other opinions are mocking us, or mocking themselves'. For that is the same thing as if one replied to my argument: 'How do you know that your conclusion is true?', but without being willing to examine the premises.[37]

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34 Leibniz to Johann Friedrich, early 1677, A VI, iv, pp. 466–474. Note that Leibniz did not have access to Burgh's letter, but only to Spinoza's reply.

35 Burgh to Spinoza, 3 September 1675, transl. in Spinoza, *Complete Works*, p. 922.

36 Spinoza to Burgh, December 1675, transl. in Spinoza, *Complete Works*, p. 949.

37 Leibniz à Johann Friedrich, Early 1677, A II, i, pp. 469–470.

What Leibniz here wrote of Burgh, he doubtless also thought of Steno: in their writings against Spinoza, the two Catholic converts revealed themselves controversialists bound by no reasonable rules of intellectual conduct.

It was however not only in relation to Spinoza that Leibniz considered Steno's polemical contributions to be unjustified attacks on rational argumentation as such. We find similar objections in his comments on the other polemical letter by Steno that he read in 1677, i.e. the second letter to Johannes Sylvius. The controversy between Steno and Sylvius was concerned with the position of St John Chrysostom on the question whether one should read Scripture by one's own lights or according to a taught doctrine. While the exact tenure of the controversy need not concern us here, Leibniz's reaction to Steno's argumentative strategies are strikingly close to his criticism of the *Ad novam philosophiae reformatorem*. While showing that Steno attributed to his protestant adversary a position that the latter did not endorse, namely that Protestants think that everyone should be autodidact in the reading of Scripture, Leibniz admitted that "one of [Steno's] letters almost scandalized [him]," because Steno "retorts so awkwardly and searches out such odd evasive answers that I almost doubted his sincerity, for I could not believe that the same Mister Steno who in the past has said such beautiful things can now say things so far removed from what could be expected from him."[38]

In both instances, in Steno's dealings with the atheist Spinoza and the Calvinist Sylvius, Leibniz saw Steno as a controversialist who aimed at the victory of his own party rather than the truth of the cause.[39] For Leibniz, however, it was of primordial importance that intellectual exchanges should proceed in an orderly manner and that one should avoid such "confused disputes" where, as Leibniz writes in a *Promemoria* on the reunion of the churches,

> the disputing parties rant to the winds, busy themselves in punctilious discussions, swerve from the issue in digressions, change the order, answer only to that which they find convenient, mask the adversary's objections or solutions, try to escape them through derision or invectives, employ repetitions, do not distinguish the job of the respondent from that of the opponent nor that of the one who must prove from that of the one who must not.[40]

38 Leibniz, *Lettre à un amy*, A VI, iv, pp. 2189–2190.

39 For a recent assessment of Steno as a controversialist, see Miniati, *Steno's Challenge for Truth*, pp. 213–233.

40 Leibniz, *Promemoria zur Frage der Reunion der Kirchen*, November 1687, A I, v, p. 11, transl. in Leibniz, *The Art of Controversies*, pp. 248–249.

Unfortunately, Steno provided prime examples of such "confused disputing," as is confirmed by the following joint comment on the two open letters:

> Letters by Mister [Steno]. I must confess to you that I am not happy with them. I would say that he very often proceeds with no proof, and that the proofs that he does provide are not always solid. Such defects are so common and so often found in even the best authors that I am not so surprised that Mister [Steno] is not free from them. But I cannot simply conceal those that are less ordinary that will appear striking to a reader of good sense. One is that he speaks in a rather awkward way and does not here display any talent for explaining himself succinctly; another one is that he prevaricates when elucidating even the clearest things, rather than admitting candidly the things that speak in his adversary's favor.[41]

For Leibniz, an irenic and conciliatory thinker if ever there was one, always thinking, as he says, that "there is truth on both sides,"[42] this was no negligible offence. Indeed, it may even have been the greatest intellectual sin in his book, because it gave away a lack of "good intentions." It testified to an intellectual attitude and conduct not aimed at the public good and the glory of God, but at the victory of the speaker's own opinion. It spoke of an uncharitable lack of regard for that part of the truth which is situated on the opponent's side.

4 Leibniz on Steno and Christian Humility

The second major reason for Leibniz's disappointment with Steno concerns what he considered an abusive understanding of Christian humility. Let us consider a long section from Steno's 1677 letter to Leibniz where he explains in more detail the reasons for his disillusion with Cartesian natural philosophy:

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41 Leibniz, *Lettre à un amy*, A VI, iv, p. 2189, note. Similarly, Leibniz concludes his comment on Steno's reply to Sylvius: "I prefer when controversies are treated with ingenuity, without squabbles and partiality, and that one recognizes in good faith the difficulties that occur, without avoiding them through strained replies. Proceeding frankly and sincerely will touch honest people and will do more good than bad to the party one has undertaken to defend" (ibid., A VI, iv, p. 2196).

42 Leibniz, *Praefatio ad libellum elementorum physicae*, 1678–1679 (?), A VI, iv, p. 2009, transl. in Leibniz, *Philosophical Papers and Letters*, p. 289.

> I thus tell you that, [while] in this country of freedom where people practice their profession very freely and read all sorts of books, at a time when I still had great esteem for Descartes' philosophy and for all of those who were praised for their knowledge of that same philosophy, a Swedish friend once brought me the lungs of a cow with the heart still attached to them, so that I may study the substance of the lungs. After having finished with the lungs, we had the idea of boiling the heart in order to see whether the substance was muscular or not, and the first fibers of the heart that I came upon, after having boiled it and removed the membrane, directed me towards the lower point and from there on upwards to the upper point, a discovery that explains the entire structure of the heart and which, until then, was unknown to everybody and directly contrary to what both the greatest and the most dangerous philosophers took to be demonstrative truth, to the point of affirming that those who did not subscribe to their opinion about the heart did not understand mechanics. Shortly after, some afternoon, I had the idea of making a comparison between the structure of the heart and the structure of the muscles, both points on which I took Descartes' system to be doubtlessly true. To this purpose, I took the foot of a Rabbit I had dissected a little earlier; and the first muscle I took from it showed me the structure of the muscle which until then had not been known to anybody and that completely overturned Mr Descartes' system.[43]

Leibniz had no objections to this account or to the conclusions Steno drew from his experiments regarding the value of Descartes' physiology. Indeed, in a letter to Malebranche from 1679, Leibniz even referred to these discoveries as decisive for the refutation of Descartes: "The most able anatomists [Leibniz first wrote: *Mons. Stenonis*, then struck it out] think that the usage of the pineal gland is very unlikely and that the movement that Mister Descartes attributes to the heart and to the muscles is destroyed by experience."[44] He repeated this in yet another letter from 1679, this time to Tschirnhaus: "Mister Steno has shown experimentally that Mr Descartes was completely mistaken in the

43 Steno to Leibniz, November 1677, A II, i, p. 577. The translation of the passage is delicate. Steno's French is imperfect and his syntax often flawed. I have not attempted to translate Steno's broken French into equally broken English. I have remained as close to the text as possible, relating (what I take to be) the sense of his statements while still respecting English grammar.

44 Leibniz to Malebranche, 22 June (2 July) 1679, A II, i, p. 718.

opinion he had regarding the movement of the heart and the muscles."[45] But most importantly, Steno's name showed up again some fourteen years later in an excerpt from a letter from Leibniz to Claude Nicaise, published in the *Journal de Sçavans* in April 1693:

> It seems that Mr Descartes had not sufficiently grasped Kepler's important discoveries in astronomy, which have subsequently been verified. His man is extremely different from what man truly is, as Mr Steno and others have shown. The knowledge he had of salts and of chemistry was very thin indeed; and this is the reason the things he says about it, including what has says about minerals, is mediocre.[46]

This text is important, not so much for its contents as for the context in which it was published. Leibniz's 1693 publication in the *Journal des sçavans* was an extremely strategic text destined, on the one hand, to criticize the Cartesians—German and Dutch Cartesians in particular: Schweling, Schotanus, Peterman, and others—for slavishly following their master and stifling scientific invention and, on the other hand, to express his full support of Pierre-Daniel Huet, a French erudite close to the Jesuits whose virulent anti-Cartesian treatise, the *Censura philosophiae cartesianae* of 1689, Leibniz much admired.[47] It is in this context that the appeal to Steno appears: as an anatomist, Leibniz considered Steno an anti-Cartesian ally, together with Huet, Pellisson, Thévenot, Nicaise and others, including to some extent even Pierre Bayle. In short, he fully agreed with Steno's conclusions regarding the ineptitude of the Cartesians in the 1677 letter, and he drew on Steno's anatomical discoveries in the context of his anti-Cartesianism, in order to demonstrate the falsity of Cartesian natural philosophy.

Leibniz did, however, take a considerably less positive outlook on the more general lessons about intellectual behavior that Steno believed we should learn from his discovery of Descartes' mistakes. Steno thus pursued his development:

> 1. If these gentlemen, almost universally admired by the learned, think that they have provided indubitable demonstrations regarding things that

45 Leibniz to Tschirnhaus, [1679], A II, I, p. 781. See also Andrault, "Introduction," p. 20.

46 Leibniz, "Extrait d'une Lettre de M. Leibnis a M. l'Abbé Nicaise, sur la philosophie de M. Descartes," in *Journal des sçavans*, nº 15, 13 avril 1693, pp. 163–165. The original letter dates from 5 June 1692 (= A II, ii, pp. 532–538).

47 For a detailed study, see Lærke, *"Ignorantia inflat*. Leibniz, Huet and the Critique of the Cartesian Spirit," pp. 13–42.

> a ten-year old boy can prepare for me in an hour, so that without any use of words, but simply by observing them, they overthrow the most ingenious systems of these great minds, then what assurance can I have of other, more subtle things that they boast about? What I mean is this: If they have erred to such a degree when it comes to material things that are laid before our senses, what assurance can they give me that they are not equally mistaken when dealing with God and the soul?
>
> 2. If God reveals the errors of these great minds to me at the very moment when I am admiring them most, this should not be taken as a mere coincidence but recognized as [an expression of] God's goodness. And even though I have not entirely abandoned the doctrine [of Descartes] which does contain some true things, I have however gradually felt this excessive admiration come undone and I have come to know the weakness of the human mind and the precipices toward which it is lead by presumption.[48]

The second part of this passage reveals an important aspect of Steno's attitude towards scientific research after his conversion, namely his critique of human presumption and weakness of reason, by reference to what he also terms "Christian humility."[49] On his own account, this "Christian humility" brought him to abandon scientific research.

Now, Leibniz, an admirer of Bacon's *The Advancement of Learning* and a tireless promoter of science, did not care much for such arguments. But he did not simply reject Steno's conception of Christian humility. In a sense, Leibniz agreed with Steno that scientific curiosity is a turbulent force that had to be systematically "curbed" in order not to become unruly and presumptuous.[50] For example, when criticizing the conduct of modern philosophers, Cartesians in particular, Leibniz recognized that their "disorder [...] is nourished by human curiosity."[51] He also agreed that humility should play a role in moderating curiosity. For Leibniz, humility was a virtue to the extent that it served to render us less sure of ourselves and incited us to take a step back from our own scientific activities, a kind of intellectual self-scrutiny, in French described by the reflexive verb *s'aviser* and in German by the expression *sich Begreifen*. Leibniz discusses these expressions at length in his 1692 *Animad-*

48 Stensen to Leibniz, November 1677, A II, i, p. 577.

49 Ibid., p. 578.

50 Leibniz, *Elementa rationis*, April–October 1686, A VI, iv, p. 726.

51 Ibid., A VI, iv, p. 726.

versiones in partem generalem Principiorum Cartesianorum,[52] arguing that the Cartesians suffered from patent lack of such self-scrutiny and meditation on their own practices. As a result of this, they had become culpable of excessive self-glorification and intellectual sectarianism. What Steno says about the Cartesian "Gentleman" in the 1677 letter to Leibniz is not very far removed from such a critique.

Leibniz's problem with Steno's position was, of course, that the latter's justified critique of Cartesian science too rapidly turned into an unjustified attack on science as such, thus taking too far a criticism whose legitimate aim was to moderate scientific curiosity, not rejecting it altogether. Leibniz makes this point neatly when developing an analogous critique of Pierre Bayle's skeptical stance in the *Dictionnaire historique et critique*, stating that "he declares himself against reason when he could have contented himself with blaming the abuse of it."[53] In fact, contrary to what Steno suggested, not all philosophers were imbued with false Cartesian natural philosophy; many were in fact more attached to the truth than to the master of some philosophical sect, "enlightened and well-intentioned" as Leibniz called them.[54]

5 The Enlightened Love of God

It should now be clear why, to what degree and in what sense exactly Leibniz thought that Steno's conception of Christian humility stifled the practice of *true science*. But why did Leibniz, as we have seen, also write to Hermann Conring in the letter already cited above that Steno's abusive understanding of Christian humility and adversity to scientific study had deprived him of "a constant motive for praising God," that is to say, deprived him of a motive for *piety*? Why, by Leibniz's lights, was it contrary to piety and not just contrary to public utility and the advancement or learning to renounce upon the scientific study of nature? The reasons for this third and last disappointment, with which I will conclude, are to be found in Leibniz's conception of the *love of God*. Hence, among the replies that Leibniz provided on Spinoza's behalf in his comments on the *Ad novam philosophiae reformatorem*, we find the following statement:

52 Leibniz, *Animadversiones in partem generalem Principiorum Cartesianorum*, 1697, GP IV, p. 362, transl. in *Philosophical Papers and Letters*, p. 388.

53 Leibniz, *Essais de théodicée*, § 45–46, GP VI, pp. 75–76. For a detailed analysis of Leibniz's reception of Bayle's *Dictionnaire*, see Lærke, *Les Lumières de Leibniz*, pp. 205–283.

54 See in particular Leibniz, *Mémoire pour des personnes éclairées et de bonne intention*, 1692 (?), A IV, iv, pp. 612–621.

> Only few people know what the love of God above all things consists in, even though it is the principle of true religion. This love is greater to the extent that it is more enlightened. Those who possess it from demonstration possess it more firmly and more perfectly, if only their practice conforms to the theory, something one can achieve through exercise.[55]

The notion of "enlightened love of God" suggested in this passage is absolutely central to Leibniz's philosophical practice.[56] He often advanced that his own philosophy was destined to "enlighten" and he bestowed a systematic sense on that notion. Hence, for Leibniz, "the pieces of knowledge that enlighten our mind are those that are distinct, i.e. that contain the causes or reasons," in opposition to the knowledge that "guides the [mind] blindly," such as the knowledge of an artisan which has been obtained "through experience and tradition." Moreover, Leibniz claimed about such enlightenment that "only this knowledge is good in itself; all the rest is instrumental [*mercenaire*]."[57] As for the notion of "enlightened love of God," Leibniz probably borrowed it from Malebranche while giving it a new meaning.[58] In Malebranche, enlightened love of God was a kind of intellectual love, opposed to instinctive or sensitive love.[59] For Leibniz, enlightened love of God was nothing less than the highest moral, epistemological, and theological virtue. As he wrote in the *Essais de théodicée*, "true piety and even true felicity consist in the love of God, but an enlightened love, where ardor is accompanied by light."[60] Loving God in this manner was, for Leibniz, not a recommendation but an obligation:

> [...] God also wishes that we do not omit anything on our side and that we use, when the occasion arises and each according to our vocation, the perfection that he has bestowed upon human nature. And since he has made us so that we may know and love him, we cannot work too hard toward that goal, nor can we make a better use of our time and our forces,

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55 Leibniz, *Autre lettre au mesme*, A VI, iv, p. 2200.

56 For details, see Lærke, *Les Lumières de Leibniz*, pp. 58–60.

57 For all four passages, see Leibniz to Ernst Von Hessen-Rheinfels, 8 December 1686, A II, ii, p. 129.

58 See Leibniz, *Aus und zu Malebranche, De la Recherche de la vérité*, 1686–1699 (?), A VI, iv, p. 1819.

59 See Malebranche, *De la recherche de la vérité*, I, v, ed. Bardout, vol. II, pp. 151–152.

60 Leibniz, *Essais de théodicée*, Preface, GP VI, p. 27.

> if we are not elsewhere occupied by public matters and by the salvation of others.[61]

If we must thus "join enlightenment to ardor" so that "the perfection of the understanding may accomplish those of the will,"[62] this does not imply an obligation to effectively *know* the nature and will of God. Enlightened love of God is a *will* to know, a will that lets itself be guided by the understanding, a certain disposition of the mind that Leibniz also describes as a "state of mind" (*situation d'esprit*).[63] But it was exactly that "state of mind" that Steno, according to Leibniz, had relinquished by adopting his abusive conception of Christian humility, thinking that it consisted in the submission of reason to Church doctrine. Quite to the contrary, by Leibniz lights, exploring nature through science was an integral part of the effort to know God through his creation that is the true mark of love of God and thus of piety.[64]

The same theme runs like a red thread throughout the entire 1679 *Dialogue*. The dialogue focuses on the nature of the love of God. The question is: Why do we take so much trouble with theological controversy, with dogma and theory, when, according to one received doctrine, the simple practice of loving God suffices for salvation? Poliandre here first defends the distinctly Roman Catholic position according to which "it does not suffice to love God; one must obey his will, that is to say the Church which is the interpreter of it." Théophile, on the contrary, insists that "he who truly loves God above all things will not fail to execute what he knows to be in accordance with his orders."[65] At the outset, their opposition is fairly clear. As already mentioned, Poliandre is however a more malleable interlocutor than the real Steno, and his position is remodeled and reformulated throughout the dialogue so as to allow for a final Leibnizian conciliation of positions. We find an important example of this when Poliandre finally concedes that he is

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61 Leibniz to Ernst von Hessen-Rheinfels, 8 December 1686, A II, ii, p. 130.

62 Leibniz, *Essais de théodicée*, Preface, GP VI, p. 28.

63 Ibid.

64 On this point, see also Leibniz to Ernst von Hessen-Rheinfels, 10 (20) May 1684, A I, iv, p. 331: "Mr Steno put much work into this [i.e. making observations about the terrestrial globe in order to determine its ancient shape from the marks of it that still remain], but since he has been engaged in [religious] controversy, he has abandoned this research, and yet it is very useful for religion."

65 Leibniz, *Dialogue*, A VI, iv, p. 2220.

> willing to grant that the love of God above all things suffices [...]: but it must be veritable, serious, ardent and active. For we strive to get to know the wishes of the person that we love, and to act in accordance with it. A true lover is attentive to even the smallest movements of the person upon whom his wellbeing depends.[66]

In these determinations, it is not hard to recognize the notion of *amour éclairé de Dieu* that arguably forms the basis of Leibniz's entire intellectual enterprise. But if, contrary to Poliandre, the intellectual conduct of the real Steno testified to an intellectual attitude adverse to the enlightened love of God, little good could come of his activities. Consequently, for Leibniz, there was little left to say other than what he later concluded in the *Essais de théodicée*, with a caricature that nonetheless neatly summarized his exchanges with the newly minted bishop in Hanover, namely that Steno "was a great anatomist and deeply versed in natural science; but [...] from being a great physician he became a mediocre theologian."

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66 Ibid., p. 2221.

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PART 2

Anatomy and Metaphysics: Steno and Cartesianism

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CHAPTER 4

Human Brain and Human Mind: The *Discourse on the Anatomy of the Brain* and Its Philosophical Reception

Raphaële Andrault

1 Introduction

The study of the anatomy of the brain has always had an ambiguous relationship with philosophical discourse on mental faculties.[1] Distinguishing the subject matter of each discipline is not an easy task. The philosophical reception of Nicolas Steno's *Discourse on the anatomy of the brain* (1669) provides a good illustration of the way in which they are intertwined and puts into focus the manner in which the anatomical study of the brain can be metaphysically instrumentalized.

The *Discourse* was pronounced in Melchisédec Thévenot's Parisian salon in 1665 and published in 1669. It essentially consists in a thorough review of the contemporary state of anatomical studies of the brain. It includes a description of the most widespread errors regarding the structure of the brain, a list of reasons why such errors had so far been committed, and a brief proposal to amend the discipline. At first sight, this modest and technical text contains no philosophical claims, nor does it propound a thesis about the nature of the soul or its relationships to the brain. It does not even connect cerebral structures with animal or mental functions. Yet it received considerable and durable philosophical attention, doubtless because it includes a short refutation of the Cartesian account of brain anatomy. Hence Jean Chapelain, a Parisian scholar who adhered to Gassendi's philosophy, emphasized the polemical importance of Steno's *Discourse*:

> Stensen the Dane has performed the most marvelous experiments ever in this field. He has even forced the obstinate and dogmatic Cartesians to

1 I use the following additional abbreviations: Descartes: Ariew = *Philosophical Essays and Correspondence*, ed. R. Ariew, Indianapolis/Cambridge: Hackett 2000. Steno: *Discours* = *Discours sur l'anatomie du cerveau*, Paris: Robert de Ninville 1669.

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> admit the error of their leader with regard to the gland of the brain and its function [...], on which he based all the operations of the reasonable soul.[2]

This quotation is famous in the history of Cartesianism. Afterwards, it became standard to appeal to Steno's authority in order to contrast natural man with the man invented by Descartes' ingenious mind (like Leibniz did)[3] or even to discredit the idea of dualistic mind-body interaction, by pointing to Descartes' somewhat fanciful brain anatomy (as did Spinoza and, long after, Franz Gall).[4] In short, the long story of the *Discourse*'s philosophical reception suggests that Steno, in the *Discourse*, took a more general stand against the impasses of dualism itself. And such a hypothesis appears all the more legitimate if we consider Steno's criticism of the philosophy of Descartes in later texts, notably his letter to Spinoza, *Ad novae philosophiae reformatorem* (1675):

> Scrutinize, I pray, all those demonstrations of yours and bring me just one which shows how the thinking thing and the extended thing are united [...]. So the entire philosophy of Descartes, however diligently examined and reformed by you, cannot explain to me in demonstrative form even this single phenomenon, how the impact of matter on matter is perceived by a soul united to matter.[5]

Inferring a refutation of the so-called metaphysical dualism[6] from the rejection of Descartes' brain anatomy is, however, questionable for two reasons. Firstly,

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2 Thévenot to Huet, 6 April 1665, in J. Chapelain, *Lettres*, ed. T. de Laroque, Paris: Imprimerie Nationale 1883, vol. II, p. 393, note 3; transl. by G. Scherz in *Nicolaus Steno's Lecture on the Anatomy of the Brain*, Hafniae: A. Busck 1965, p. 70.

3 Leibniz, *De la philosophie cartésienne*, 1683–1685 (?), A VI, iv, p. 1486: "Mr Steno was disabused of Cartesianism when he discovered just how much the human body truly differed from Descartes' man."

4 Spinoza, *Ethics*, V, Preface, in *Complete Works*, p. 365. For Gall, see *Anatomie et physiologie du système nerveux en général et du cerveau en particulier*, p. 24 (for a critique of the idea that the soul is simple) and pp. 316–317 (for the allusion to Steno's critique of Descartes' fanciful brain anatomy).

5 OT I, p. 101 (transl. in Spinoza, *Complete Works*, Letter 67A, p. 933): "Excute, quaeso, omnes demonstrationes tuas, et vel unam mihi afferto de modo, quo cogitans et extensum uniuntur [...] [A]deoque omnis Cartesii philosophia, ut ut quam diligentissime a te excussa et reformata, non possit mihi vel hoc unicum phaenomenon demonstrative explicare, quomodo nempe materiae in materiam impulsus ab anima materiae unita percipiatur."

6 I shall not discuss the relevance of such a label here. This would require a study of the *Passions*

Steno's *Discourse* not only refutes Descartes' description of the pineal gland. It also refutes Thomas Willis' cerebral anatomy, which was philosophically closer to Gassendi, as well as the hypothesis of the "Ancients"[7] with regard to the cerebral seats of memory, imagination and judgment—both positions that are not regarded as dualistic. Secondly, and most importantly, the approach to brain function that Steno recommends seems itself to depend on the idea of a dualism between *res extensa* and *res non extensa*.

The aim of this chapter is threefold: (1) to show that Steno's position in the *Discourse* is irreducible to the ways in which it was used both by Descartes' detractors and by his followers; (2) to clarify the link between Steno's anatomical critique of Descartes and his metaphysical position, or lack thereof; (3) to contribute to current discussions regarding "cerebral localizations," i.e. the assignment of specific mental functions/faculties to specific parts of the brain. I will proceed in three steps. First, I will present the specificity of Steno's criticism of Descartes in the medical landscape of the time, providing the necessary background for understanding its reception by late seventeenth-century philosophers. Next, I will define Steno's position as "critical experimentalism" and discuss the question of a possible influence of Descartes on Steno's methodology. Finally, I will show how a late manuscript by Steno sheds new light on the issue of dualism in cerebral anatomy.

2 A Factual Critique of Descartes

The *Discourse on the Anatomy of the Brain* begins with a confession of ignorance: in 1665, Steno admits, anatomists ignore both the true structure of the brain and the nature of its main parts, be it the animal spirits, the white and grey substance, or the ventricles. What learned people think they know is at best uncertain. As proof, Steno very briefly invokes the anatomical "system" of the "Ancients," Willis' system and some of Descartes' hypotheses, all of which

of the Soul and the *Sixth Meditation*. By "dualism," I simply mean the substantial distinction between *res extensa* and *res cogitans*.

7 The hypothesis that Steno presents as being that of the "Ancient" was usually attributed to Thomas Aquinas, Duns Scot, Albert the Great, Avicenna and Averroes. It was also defended by Ambroise Paré (1509?–1590). See his *Œuvres completes*, pp. 216–217, where he localizes imagination in the two first ventricles, judgment in the third ventricle, and memory in the fourth ventricle. Many Ancient physicians, however, defended an alternative thesis inspired by Galen according to which there are no distinctive "seats" in the brain. In the French Renaissance, this was the case of Andre Du Laurens (1558–1609).

can be proved wrong by means of accurate anatomical demonstration.[8] Next, Steno goes on to explain the reasons for these mistakes, which are due partly to the softness and fragility of the brain, partly to the methods of dissection, and partly to public dissections in anatomical theaters, which were mainly planned to distract. Finally, Steno indicates technical and institutional ways to improve brain anatomy, such as the invention of a circular saw or drugs softening the skull, the establishment of a new taxonomy, or the development of comparative and pathological anatomies. Thus, the critique of Descartes constitutes only a small part of the text. Steno does however refer to the "pineal gland," in which Descartes identified the seat of the common sense,[9] as the "most famous" anatomical issue "of this century."[10] Moreover, the discussion of Descartes' descriptions of the brain is more detailed and better argued than his discussions of other descriptions, being based on a series of citations. Steno carefully summarizes Descartes' main propositions regarding the pineal gland and its surrounding parts, on which Descartes had based all of his physiological explanations of mental functions such as the will, imagination, memory, attention and sensory perception. According to Steno, contrary to what Descartes claimed, the pineal gland was not situated in the middle of the ventricles or cerebral cavities; it was not mobile; and it was not surrounded by arteries. Given its structure, the gland could not move from side to side without breaking apart; given its position, the gland could not be on the pathway of the so-called animal spirits, this neuromuscular fluid composed of the most subtle particles of the blood that were thought to be responsible for the animal sensory-motor functions.

These criticisms are decisive: it was mainly by referring to various inclinations of the gland that Descartes explained the diversity of perceptions potentially felt by the soul.[11] If, however, as Steno held, the gland is neither suspended

8 In Steno's *Discourse, démontrer* means roughly "to dissect and to show."

9 See Descartes to Mersenne, 24 December 1646, in AT III, p. 264: "[T]he [pineal gland] is the only solid part in the brain that it is unique, therefore it should be the seat of the common sense, that is to say the seat of the thought and consequently of the soul [*il n'y a que la* [*glande pinéale*] *de partie solide en tout le cerveau, qui soit unique, il faut de nécessité qu'*[*elle*] *soit le siège du sens commun, c'est-à-dire de la pensée, et par conséquent de l'âme*.]" See also *Passions de l'âme*, art. 32, AT XI, p. 353.

10 Steno, *Discours*, p. 43, transl. in KM, p. 519: "Je vous en rapporterai ici un exemple, dans une question Anatomique, la plus fameuse de ce siècle. Ceux qui nient la continuation de la glande pinéale avec la substance du cerveau […]." Today called the epiphysis, the pineal gland was named after its pine cone shape.

11 Descartes, *Passions de l'âme*, art. 34, AT XI, pp. 354–355, transl. Ariew, p. 308: "Let us then

nor mobile, it cannot contribute to the transmission of sensory impressions. If the gland is not placed in the middle between the four ventricles nor on the pathway of the animal spirits, it cannot account for voluntary movement, attention or even memory.[12] However, no matter how disastrous they could seem to Cartesian anthropology, such psychophysical consequences were not mentioned by Steno in the *Discourse* at all. Steno simply noted that disproving the existence of arteries around the gland was "a matter of no little consequence for the system of M. Descartes, since the separation of the spirits and their movement depend on it."[13]

Steno's critique of Descartes was purely anatomical, descriptive and morphological. Yet, precisely because it was rigorously factual, it was considered all the more decisive. Steno was neither the first nor the only one to criticize Descartes' psychophysiology by means of anatomical arguments. For instance, in the third revised and augmented edition of the *Anatomia reformata*, which appeared in 1651, two years after the publication of Descartes' *Passions of the soul*, Bartholin dedicated a long passage to discussing the pineal gland and a six point refutation of the Cartesian description.[14] In his *Cerebri anatome* published in 1664, Thomas Willis briefly mentioned Descartes' account of the pineal gland and rejected the functions that Descartes ascribed to it.[15] No other

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conceive here that the soul has its principal seat in the little gland that exists in the middle of the brain, from which it radiates forth through all the remainder of the body through the mediation of the spirits, nerves [etc.]. Let us here add that the small gland that is the principal seat of the soul is so suspended between the cavities containing the spirits that it can be moved by them in as many different ways as there are sensible differences in the objects."

12 Regarding memory, see Descartes, *Passions de l'âme*, art. 42, AT XI, p. 363, transl. Ariew, p. 311: "Thus when the soul wishes to recollect something, this volition causes the gland, by inclining successively to different sides, to thrust the spirits toward different parts of the brain until they come across that part where the traces left there by the object we wish to recollect are found." Regarding attention, see art. 43, ibid.: "Thus when we wish to apply our attention for some time to the consideration of one particular object, this volition holds the gland for the time being to the same side."

13 Steno, *Discours*, p. 21, transl. in KM, p. 513.

14 See Bartholin (ed.), *Anatomia ex Caspari Bartholini parentis Institutionibus* (1651), pp. 336–337. For a more detailed account, see Andrault, "Introduction," in Sténon, *Discours sur l'anatomie du cerveau*, p. 7, and Andrault, Crignon, Buchenau, Rey (eds.), *Médecine et philosophie de la nature humaine de l'âge classique aux Lumières*, pp. 60–61. Thomas Bartholin was Steno's preceptor at the University of Copenhagen in 1656.

15 Willis, *Cerebri anatome: cui accessit Nervorum descriptio et usus* (1664), chap. XIV, p. 169.

criticism however proved to be as influential as Steno's. There are several explanations for this:

First, a comparison with Willis' or Bartholin's arguments reveals that, contrary to what could be found elsewhere, Steno's critique of Descartes remained very faithful to the Cartesian texts and, partly for this reason, could be considered particularly harmful to Cartesian anthropology.[16] According to Bartholin's criticism in the *Anatomia reformata*, the pineal gland was an ignoble gland placed on the pathway of cerebral "excrements." In addition, Bartholin argued, it was a very small, soft and colorless part of the brain.[17] These features allegedly prevented the gland from being the seat of *common sense*, understood as the part of the brain that receives and gathers sensible *species*, i. e. the images or representations of objects.[18] Hence, Bartholin evaluated Descartes' brain anatomy using criteria and terms absent from Descartes' texts. He noted for example that Descartes' system was impossible because the nerves did not touch the pineal gland. But Descartes never maintained this, even though he argued that the pineal gland was on the pathway of the animal spirits. Bartholin also invoked "sensible species" that the gland could not gather due to its small size. For this reason, Louis de La Forge, in the remarks he added to

16 Without mentioning Steno by name, Louis de La Forge's *Traité de l'esprit de l'homme* (1666) rebukes Steno's objections to Descartes' theory regarding the localization of the pineal gland. La Forge mainly argues against the claim that Descartes' brain anatomy is impossible. Such a strategy implies casting doubt on the accuracy of Steno's public dissections and appealing to anatomical consensus, i.e. the very consensus challenged by Steno in the *Discourse*. More generally, La Forge evokes possible differences between a living and a dead brain as well as between animal and human brains in order to dismiss critique based on public dissection and experimentation. See La Forge, *Treatise on the Human Mind*, pp. 152–153: "How is there room to deny that this gland belongs to the ventricles since all the anatomists agree that is originates from two ligaments of nerves from the surface of the medullar trunk […]? […] Thirdly to their objection that this gland cannot move, I reply that if they can convince us that all the parts of a living animal brain are as compacted as those of the head of a dead calf, their objection may be acceptable and we would possibly agree with it. But there is no reason to believe that is the case while the animal is alive […]. There is nothing therefore to prevent our little gland from being the principal seat of the soul."

17 For a more detailed account, see Andrault, *La vie selon la raison*, p. 308.

18 The status of those species varies. For someone like Du Laurens, they appear at first to be material since they emanate from material objects. Nonetheless, their reception through the brain and treatment by reason can make them immaterial and universal (see *Toutes les œuvres de M. A. du Laurens* (1621), pp. 308–309). Such mixing of material and immaterial components in the processes that are first physiological, then intellectual, does not appear to be problematic to him.

the first French edition of Descartes' *Man* in 1664, had no difficulties in refuting Bartholin's famous criticism point by point, arguing for instance that such criticism mistook sensible species for "small pictures of tapestry depicted in the back of the eye."[19] In fact, according to Descartes, what is transmitted from the perceived objects to the seat of the common sense, i. e. the pineal gland, are only the mechanical repercussions of nervous movements.[20] As for Willis, he used the size of the pineal gland to refute Descartes' notion that it is the seat of soul. His reasoning was the following: animals have very little imagination and memory—two mental faculties that allegedly depend on the soul. Thus, if the pineal gland were the seat of the soul as Descartes held, or even simply if the gland played an important part for these mental faculties, it should be smaller in animals. Anatomy demonstrates that this is not the case. Therefore, the pineal gland is not the seat of the soul:

> Below the chambers of the Optick nerves [...] is placed the Pineal Glandula [...]; this is not only found in Man and four-footed Beasts, but Fowls and Fishes [*sic*] also are endued with the same. Wherefore, although from hence it may be concluded, that this is of necessary use; yet we can scarce believe this to be the seat of the Soul, or its chief Faculties do arise from it; because Animals, which seem to be almost quite destitute of Imagination, Memory, and other superior Power of the Soul, have this Glandula or Kernel large and fair enough.[21]

But one could reply to Willis that the size of the gland did not necessarily change anything about its specific psychophysical role in living individuals endowed with thinking souls. Contrary to both Bartholin and Willis, Steno proposed a rigorously factual criticism and carefully avoided over-interpreting Descartes' texts. He contented himself with quoting Descartes' *Treatise* and demonstrating how Descartes' various anatomical statements regarding the gland could be firmly contradicted by public dissection.

Next, Steno's celebrated skills as an anatomist and public dissector made his refutation of Descartes particularly convincing. According to the *Journal des sçavans* of March 1665, during his stay in Paris Steno publicly dissected bodies

19 La Forge, "Remarques de Louis de La Forge," in Descartes, *De l'homme* (1664), p. 321.

20 On this point, see Fichant, "La géométrisation du regard. Réflexions sur la *Dioptrique* de Descartes," pp. 45–69, reedition in Fichant, *Sciences et métaphysique dans Descartes et Leibniz*, pp. 27–57.

21 Willis, *Cerebri anatome* (1664), p. 169, transl. in *Practice of Physicks* (1684), p. 87.

or organs every day,[22] and his skills at doing so were uniformly praised by those who were lucky enough to attend the demonstrations, either at the *École de médecine* or in Thévenot's salon in Paris. The enthusiasm of the public is for instance palpable in André Graindorge's letter:

> This Steno is causing a sensation. This afternoon we saw the eye of a horse. To tell you the truth, compared with him we are only apprentices. [...] He is always dissecting. He has an unbelievable patience and through practice he has gained a unique expertise.[23]

As we have already seen, Chapelain made similar comments, adding that Steno "outshined all the Ancients and all the Moderns in this sort of thing [anatomy]."[24] Thus, through his public dissections, Steno had earned an audience and a trust that goes a long way in explaining the importance given to his lecture.

Finally, the nature of this audience attending the lecture at Melchisédec Thévenot's Parisian salon arguably played a role in explaining the success of the *Discourse*. Not much is known about the exact circumstances under which Steno presented his lecture, about the people who attended it,[25] or just how similar the text published in 1669 was to the lecture Steno actually gave in 1665.[26] The content of the published *Discourse* and the reactions it

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22 See *Journal des sçavans*, 23 March 1665, ed. De Houdeville, 1685, vol. II, pp. 155–156.

23 Graindorge to Huet, 9 May 1665, in Tolmer, *Pierre-Daniel Huet, humaniste physicien*, p. 330, transl. in Grell, "Between Anatomy and Religion," p. 213.

24 Chapelain to Huet, 6 April 1665, in Chapelain, *Lettres*, vol. II, p. 393, note: "Il efface tous les anciens et tous les modernes en ce genre."

25 Between autumn 1664 and spring 1665, at least, Auzout, Petit, Huygens, Borch, Steno and Swammerdam met at Thévenot's home. Thévenot hosted Swammerdam and Steno in Paris and Issy for nearly a year. Regarding the audience at Steno's lecture and the conflicting hypotheses about whether this audience was Cartesian or anti-Cartesian, see Andrault, "Introduction," p. 17. Sophie Roux casts doubt on what she calls a "continuist genealogy, according to which an uninterrupted line connects one society to the next, and all of them to the *Académie des sciences*" ("Was there a Cartesian Experimentalism in 1660s France?," pp. 47–88, p. 59). It is this hypothesis that commentators usually refer to when listing the members of the Thévenot circle: they assume that the members of the *Académie de Thévenot* were roughly the same as the members at the *Académie de Montmor*.

26 It is not impossible that the text remained unchanged between the lecture in the spring of 1665 and the publication in 1669. See for instance Chapelain's letter to Steno, 15 March 1666, *Epistola* 20, in EP I, p. 187: "Mr de Graaf [...] asked me if your *On the Brain* had already been published. It ought to be done, since when you left, so little was left for it to be done

prompted from the learned community do however suggest that it answered a specific request coming from natural philosophers already familiar with Descartes' philosophy who were seeking to challenge the accuracy of Cartesian science through new observations and experiments. Among the scientists who attended Steno's lecture in Thévenot's salon, or had heard of it, Christiaan Huygens and Reinier de Graaf were eager to read Steno's text as the kind of experimental refutation of Descartes' brain anatomy that until then had been lacking.[27] Indeed, throughout the 1660's, Descartes' anatomy had already become the matter of a public debate that went far beyond Descartes' own texts. Bartholin, for instance, did not address his criticism to Descartes himself but rather to "Cartesian followers," just like Steno did in the *Discourse*.[28] And Steno should be taken seriously when he stressed that his criticism was addressed to Descartes' friends, i.e. to the physicians who mistook Descartes' "man" for natural man, rather than to Descartes himself. The latter, Steno suggested, deserved respect as a philosopher who had found a way to explain human functions with the same evidence as we explain the functions of a machine.

It is thus not surprising that, when criticizing Descartes in the preface of the fifth part of his *Ethics*, Spinoza chose to use anatomical remarks that can be found in Steno rather than the ones from Bartholin. Thus, in this preface, in addition to a metaphysical refutation of Descartes' theory of voluntary actions, Spinoza remarks: "There is the additional fact that [Descartes'] gland is not to be found located in the middle of the brain in such a way that it can be driven about so easily and in so many ways, nor do all nerves extend as far as the cavities of the brain."[29] Such a statement is surprising, given Spinoza's customary prudence when speaking of empirical, and especially medical, issues. In the *Ethics*, he restricts himself to considering the human body very abstractly as a complex union of soft, fluid and solid parts, and refrains from naming the different parts of the human body according to any anatomical taxonomy. Never-

[*Mr de Graaf* [...] *m'a fait demander si vôtre Du cerveau était publié. Cela devrait bien être fait, puisque quand vous partîtes d'ici il y avait si peu de choses encore à faire*]".

27 For de Graaf, see note 26 above. For Christiaan Huygens, see the letter from Thévenot to Huygens, 18 September 1665, in Huygens, *Œuvres complètes*, vol. v, p. 488. For Chapelain, see also his letter to Steno, 8 December 1665, in EP I, p. 184.

28 Bartholin's *Anatomia reformata* (1651) mentions Meyssonnier, Regius and Hogelande as "*Cartesii sequaces*" (op. cit., p. 336). We could add to them Schuyl, Clerselier, Gutschoven and La Forge, who edited, illustrated, and wrote the commentary in Descartes' *De Homine* (Leyde 1662) and *L'Homme* (Paris 1664).

29 Spinoza, *Ethics*, v, Preface, transl. in *Complete Works*, p. 365.

theless, Spinoza's anatomical remarks attest to the fact that philosophers of the time took Descartes' anatomy seriously—seriously enough to carefully quote and refute it even when they had sufficient reasons to dismiss Descartes' union of the soul and the body on metaphysical grounds. For Spinoza, for instance, the very idea of a proportion between the power of a motion and the strength of a will is inconceivable and the notion of a causal action between the two was already "more occult than any occult quality": "And surely, since will and motion have no common standard, there cannot be any comparison between the power or strength of the mind and body, and consequently the strength of the latter cannot possibly be determined by the strength of the former."[30]

The enthusiasm of Thévenot's circle for the *Discourse*, as well as Spinoza's keen interest in the brain dissections performed by Steno in Leiden in 1661–1662,[31] go to show that the search for a cerebral seat of sensory-motor coordination had become a major issue for natural philosophers at the time, regardless of their metaphysical orientation. Indeed, no matter whether they thought the mind was corporeal or incorporeal, indivisible or divided into a sensitive and an intellectual part,[32] causally connected to the body or only representatively related to it, they all believed that the integrity of the brain somehow determined the transmission of nervous stimulation, the execution of voluntary motions, and the capacities to remember and focus one's attention. To put it briefly, the interest in public dissections of the brain was not particularly surprising in a historical context defined by: 1) the Cartesian rejection of substantial forms and the subsequent redefinition of the attributes of mind and body;[33] 2) the recent debates about animal souls, the existence of which was denied by Descartes; 3) the major experimental advances in animal physiology, on topics such as the circulation of the blood, the lymphatic vessels, the

30 Spinoza, *Ethics*, v, Preface, transl. in *Complete Works*, p. 365.

31 See Totaro, "Ho certi amici in Ollandia: Stensen and Spinoza," pp. 27–38, p. 32; Spinoza, *The Vatican Manuscript of Spinoza's* Ethica, p. 10 and p. 68. According to Steno's 1677 denunciation of Spinoza to the Inquisition, Spinoza "paid [Steno] daily visits to see the anatomical investigations of the brain that [he] carried out on several animals in order to discover the seat where motion begins and sensation ends [*la sede del principio de moti ed il termine della sensazioni*]."

32 This was, roughly speaking, the position of Gassendi: there is a material soul, which is sensitive and common to animals and human beings. Sensation, imagination, memory depends on the movements of the animal spirits, conceived as subtle fluid flowing from the brain toward the sense organs.

33 See Ariew, *Descartes and the First Cartesians*. Ariew points out that, regardless of the diversity of doctrines put forward by the so-called "Cartesians," they all had the rejection of the scholastic substantial forms in common.

role of respiration. All this brought hope that new discoveries on the role of the cerebral parts were also imminent.

In sum, Steno was highly praised as a dissector, did not partake in endless metaphysical discussions regarding the definition of the soul, took Descartes' neurophysiology seriously enough to disprove it with the same rigor as he disproved Willis' cerebral localizations, and rejected it exclusively on the basis of morphological description. For all these reasons, his *Discourse* became a key text for those who sought to refute Cartesian philosophy on its own grounds, and this goes a long way in explaining the success of Steno's *Discourse* in the long philosophical history of Cartesianism and anti-Cartesianism.

3 A Critical Experimentalism

Steno's brain anatomy is restricted to the mere description of forms, positions, colors, size, and connection of the parts of the brain. It is solely on this ground that Steno rejected the mistakes of Willis, those of Descartes, as well as the illustrations proposed by Vesalius and Sylvius.[34] The justification for restricting himself in this way was the following: One must base hypotheses about functions only on anatomical propositions that are obvious and certain. An anatomical proposition can only be regarded as certain if several spectators and other dissectors confirm it on several occasions while adopting different ways of dissecting. As Steno stressed, it is not enough to be convinced oneself but "the evidence of the demonstration must force others to agree."[35] The role of the spectators was crucial: by paying attention to every gesture of the anatomist, they were able to confirm, for instance, that some cerebral parts were really contiguous to others and that the anatomist did not modify the shape of these parts, and so on. The way of dissecting was also decisive: chang-

34 Franciscus Sylvius (1614–1672) was Steno's teacher in Leiden. Steno also mentions Casparus Bauhinus (1560–1624) and Constantius Varolius (1543–1575) in this context (see Steno, *Discours*, p. 26).

35 Steno, *Discours*, p. 40, transl. in KM, p. 518: "Ce n'est pas même assez de s'en pouvoir éclaircir soi-même, il faut que la démonstration oblige tous les autres à en demeurer d'accord." See also *Discours*, p. 46, transl. in KM, p. 520: "It is not enough to pay exact attention at every moment, the manners of dissecting must also be changed; being as they are as many evidences of the truth of your operation. They can equally satisfy yourself and convince others [*Ce n'est pas assez d'avoir à tout moment une attention exacte, il y faut ajouter le changement des manières de disséquer; qui sont comme autant de preuves de la vérité de votre operation, et qui peuvent également vous contenter vous-même et convaincre les autres*]."

ing the approach was the only way to ensure that the dissection itself did not modify the shape and disposition of the cerebral parts. As a result, anatomical knowledge became contingent upon varied and reiterated verification by ocular witnesses. This explains why Steno deemed that most previous assertions about the brain and its main parts were dubious. As he wrote in the famous last paragraph of the *Discourse*:

> What we have seen so far, Gentlemen, on the insufficiency of the systems of the brain, on the shortcomings of the method which has been followed to dissect and to know it, on the infinity of researches which should be undertaken on men and on animals and this in the different states in which they should be examined, on how little light we find in the writings of our predecessors and on all the attention necessary when working on such delicate pieces, must undeceive those who keep to what they find in the books of the Ancients. We shall always remain in a miserable ignorance if we content ourselves with the little light they left us and if the men most prone to make these researches do not join their works, their industry and their studies to arrive at some knowledge of the truth which must be the main goal of those who reason on the subject and who study honestly.[36]

It was in the name of such a requirement of experimental certainty that Steno rejected both the Ancients' and Willis' cerebral localizations. In both cases, simply pointing to the lack of a "convincing" element, i.e. of direct observations testifying their descriptions, is tantamount to a strict refutation. The "Ancients," according to Steno, "took the anterior ventricles for the seat of common sense and destined the posterior ones to memory so that judgment, as they say, being accommodated in that of the middle can easily make its reflections on the ideas which come from one and the other ventricle."[37] But in "all that which has been asserted hitherto to establish this opinion, there is nothing convincing."[38] Even worse, the third ventricle that they based their opinion on did not exist in the way they described it. According to Steno's summary, Willis had put "common sense in the *corpus striatum* or striated body, imagination in the *corpus callosum* and memory in the cortex or in the greyish substance which envelops the white one."[39] In fact, Willis' system is a bit more complex and, so

36 Steno, *Discours*, pp. 56–57, transl. in KM, pp. 522–523 (translation modified).

37 For such a system, see Ambroise Paré, quoted in note 7 above.

38 Steno, *Discours*, p. 11, transl. in KM, p. 510.

39 Ibid.

to speak, dynamic.[40] But this matters little here.[41] What does matter is the way in which Steno dismissed these hypotheses:

> How can [Willis] be so assured to make us believe that these three operations occur in the three bodies which he destines to them? Who can tell us whether the nervous fibres start in the *corpus striatum* or whether they rather pass through the *corpus callosum* up to the *cortex* or to the greyish substance? Assuredly, the *corpus callosum* is so unknown to us that, if only one has a little wit, one can say whatever one likes about it.[42]

According to this passage, lack of certainty fully justifies dismissing any assumption. Willis was explicit about the fact that anatomy itself did not allow him to say anything about the *corpora striata*. Like Descartes, his conjectural reasoning was based on technical analogies with the way that machines work. But this did not mean that his claims on the subject were completely devoid of experimental support:

> As to the offices and uses of the streaked bodies [*corpora striata*], though we can discern nothing with our eyes, or handle without our hands, of these things that are done within the secret conclave or closet of the brain; yet, by the effects, and by comparing rationally the Faculties, and Acts, with the Workmanship of the Machine, we may at least conjecture, what sort of works of the animal function, are performed in these or those, or within some other parts of the head; especially because it plainly appears that the offices of the interior motions, and senses, as well as the exterior,

40 Put briefly, for Willis, the flow of the animal spirits or "sensory impressions" from the center (the striated body of the white substance) toward the periphery (the cortex) accounted for the imagination, while the flow from the periphery back to the center accounting for memory (images were conserved in the folds of the cortex.) As for the common sense, it was the cerebral location prolonging the spinal cord where the sensory impressions flowing in the nerves coming from the various sense organs gathered together, determining the sensory perception or internal sense (see Willis, *Cerebri anatome*, chap. XI, p. 72).

41 Malebranche gives the same account of Willis' position. See Malebranche, *The Search after Truth*, Book II, chap. I, § 2, p. 89.

42 Steno, *Discours*, p. 12, transl. in KM, p. 511 (translation modified): "*Quelle assurance peut-il donc avoir pour nous faire croire que ces trois opérations se font dans les trois corps qu'il leur destine? Qui est-ce qui peut nous dire si les fibres nerveuses commencent dans le corps rayé, ou si elles passent plutôt par le corps calleux, jusques à l'écorce ou à la substance grisâtre? Certes, le corps calleux nous est si inconnu que, pour peu qu'on ait d'esprit, on en peut dire tout ce qu'on veut.*"

> are performed with the help of the animal spirits, ordained within certain and distinct paths, or as it were small little pipes.[43]

Steno, however, refused any conjecture that could not be ascertained by witnesses, or that was not observable either directly (through anatomical demonstration) or indirectly (through comparative vivisection and complex experimental procedures.)[44] This also applied to the question of animal spirits, on the nature of which there was no certainty. As for the functional hypotheses on the use of the anatomical parts revealed by dissection, they were accepted as falsifiable premises that one should endeavor to convincingly refute, as we can see in Steno's *Myology*.[45] In this way, irrefutable assertions were established negatively through criticizing uncertain assertions that were refutable through observation and experiment. As the *Discourse* put it, "to pursue in all dissections a convincing certitude is difficult," but not completely impossible.[46] One may call this most striking and original feature of Steno's methodology "critical experimentalism." The careful refutation of the main contemporary hypotheses about brain areas and mental functions was neither counterbalanced with hypotheses about the true organization of the brain, nor combined with psychological or metaphysical assertions about the soul or sensory-motor functions. Indeed, the *Discourse* carefully avoided all considerations not based on firsthand practice and experiment.

Steno used this critical experimentalism to reject Descartes' brain anatomy and yet it seems partly justified by Cartesian arguments. Firstly, the requirement of clarity and evidence that guided Steno's refutation brings to mind Descartes' method. In the *Discourse*, the "laws of philosophy" are described in such a way as to "teach us to search the truth while questioning our certitude and not to be content before having been confirmed by the evidence of

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43 Willis, *De anima brutorum* (1672), cap. IV, in *Opera omnia*, vol. II, p. 36, transl. S. Pordage, in *Two Discourses concerning the Soul of Brutes, which is that of the Vital and Sensitive of Man* (1683), p. 27.

44 Cf. Swammerdam and Steno's experiments, showing that muscular contractions do not imply an increase of the volume of the muscles. See Kardel, *Steno on muscles. Introduction, Texts, Translation*, p. 16.

45 Steno, *Elementorum Myologiae Specimen seu Musculi description* (1667), p. 30. See Kardel, *Steno on muscles*. p. 86, for the comparison with Popper; and, specifically about this point, Andrault, "Mathématiser l'anatomie: la myologie de Stensen," pp. 505–536, p. 526.

46 Steno, *Discours*, p. 41, transl. in KM, p. 518: "[I]l est absolument nécessaire, comme je l'ai déjà dit, de chercher dans les dissections une certitude convaincante. J'avoue bien que cela est difficile; mais je connais aussi que [cela] n'est pas tout à fait impossible."

the demonstration."[47] In a letter about his conversion published in 1680, Steno used Descartes' skeptical doubt against what he saw as Descartes' dogmatism.[48] A second feature of Steno's approach that appears to be inspired by Descartes concerns the machine analogy, to which he appealed no less than three times in the *Discourse* when explaining both his severity of judgment with regard to some of the most famous anatomists and his own silence regarding the functioning of the brain: "I did not say anything so far of the functions of the parts nor of the actions called animal because it is impossible to explain the movements occurring through a machine if the structure of its parts is not known."[49] He went on to state that "it remains to do what we would do for any other machine; I mean to dismantle it piece by piece and to consider what these can do separately and together."[50] The machine analogy illustrates the importance of anatomical analysis: the description of parts is a necessary condition for understanding the functioning of the whole.

Steno's *Discourse* represented an even more powerful tool for Descartes' detractors, as its strict experimentalism and factual refutations were justified by arguments that seemed to be borrowed from Descartes' philosophy. It is beyond doubt that Steno knew Descartes' natural philosophy and epistemology very well. At the very least, he embraced the requirement of clarity and distinctness as the feature of knowledge that rendered doubt impossible. And in 1659, Steno alluded to the necessity of testing a hypothesis regarding the role of the lungs by investigating "more carefully and systematically according to Descartes' method."[51] One can be inspired by some methodological principles of Descartes while deploring the dogmatic understanding of Descartes' writings by his more sectarian followers. This, apparently, was the case with Steno.[52]

One cannot however, reduce Steno's critical experimentalism to Cartesian natural philosophy. First, the machine analogy was never specific to Cartesian physiology only,[53] and Descartes' various readers used this analogy to support antithetical claims about the importance or usefulness of anatomy.[54] Moreover,

47 Steno, *Discours*, p. 50, transl. in KM, p. 520.

48 See Steno, *Defensio et plenior elucidatio epistolae de propria conversione*, in OT I, p. 388.

49 Steno, *Discours*, p. 53, transl. in KM, p. 521 (translation modified).

50 Steno, *Discours*, p. 33, transl. in KM, p. 516.

51 N. Steno, *Chaos-manuscript, Copenhagen, 1659*, col. 37, p. 123.

52 See Olden-Jørgensen, "Nicholas Steno and René Descartes: A Cartesian perspective on Steno's scientific development," 149–157.

53 See the comparison with the clock in Severino, *Zootomia democritaea* (1645), chap. I, p. 38, p. 43.

54 La Forge used this analogy to defend the relevance of Cartesian hypotheses about hidden

Steno's strict experimentalism faithfully reflects the way in which the *Académie Thévenot* distinguished itself from other Parisian scientific circles. According to the historians Harcourt Brown and Trevor Mc Claughlin, this *Académie* was also known as the *Compagnie des sciences et des arts* and its program was detailed in the *Ebauche du project de ce que doit faire la Compagnie à l'avenir*.[55] The aim of this learned society was to perform as many experiments and to discover as many novelties as possible, for the use of mankind. More specifically, the aim was to strive to find out "the construction and movements of the human body by the means of chemistry, anatomy and medicine, so as to preserve and restore the health that is the most precious thing in life."[56] In order to do so, it was important "to disabuse the World of all vulgar errors that have been accepted for so long as true for lack of experiments required to discover their falseness."[57] According to this experimental project, it was essential to leave aside religious or metaphysical topics—and if such topics were to be mentioned, it could only be incidentally, to the extent that they were related to physical matters.[58] Sophie Roux speaks of the "radical experimentalism" of this *Compagnie*, i.e. "the doctrine according to which the true work of those

components of the human body and to illustrate the limits of anatomy (see Andrault, "Introduction," p. 69).

55 See Brown, *Scientific Organization in Seventeenth-Century France* (*1620–1680*), and T. McClaughlin, "Sur les rapports entre la Compagnie de Thévenot et l'Académie royale des Sciences," p. 235, note 2. See also Schiller and Théodorides, "Sténon et les milieux scientifiques parisiens," p. 162. On this, see also Roux, "Was there a Cartesian Experimentalism in 1660s France?," p. 69. For the note, see Huygens, *Œuvres*, vol. IV, pp. 325–326.

56 Huygens, *Oeuvres*, vol. IV, p. 325: "Le dessein de la Compagnie est de trauailler à la perfection des Sciences et des Arts, et de rechercher generalement tout ce qui peut apporter de l'utilité ou de la commodité au Genre humain et particulieremt a la france. Pour paruenir à ce dessein l'on trauaillera a faire des experiences et à decouurir le plus de nouueautez que l'on pourra tant dans le Ciel que sur la Terre par les obseruations Astronomiques et Geographiques avec les grandes Lunettes, les microscopes, et tous les autres instruments necessaires. On trauaillera a apprendre plus particulierement la construction et les mouuemens du Corps humain par le moyen de la chymie, de l'Anatomie, et de la Medicine pour pouuoir conseruer ou restablir la santé qui est la chose la plus pretieuse de la vie."

57 Ibid. p. 326: "Enfin on s'estudiera à detromper le Monde de toutes les Erreurs Vulgaires qui passent depuis si long temps pour des veritez, faute d'auoir faict une fois les experiences necessaires pour en decouurir la fausseté."

58 Ibid. p. 328: "On ne parlera jamais dans les Assemblées des misteres de la Religion ny des affaires de l'Estat: Et si l'on parle quelque fois de Metaphisique, de Morale, d'Histoire ou de Grammaire etc. Ce ne sera qu'en passant, et autant que cela aura du rapport à la Physique, ou au commerce des hommes."

who study things of nature is nearly exclusively to carry out experiments in a socially closed space."[59] The *Compagnie* was partly inspired by the *Royal Society* and created to exchange with it. Huygens' program, however, shows that experimentalism was not exclusively promoted and embodied by English natural philosophers.

One may wonder where this radical experimentalism came from. It can partly be linked to Francis Bacon whom both Thévenot and Steno read.[60] It is also possible that Thévenot's *Compagnie* was partly guided by Descartes' method, in particular the sixth part of the *Discourse on method*. Eventually, however, the members of the *Compagnie* strongly opposed what they saw as groundless speculation and dogmatism among the Cartesian *sectateurs*.[61] One should not overestimate the influence of figures such as Descartes and Bacon. Many natural philosophers of the time read Descartes and Bacon, but they understood and used them in different ways. Moreover, particularly in relation to Steno, one should not underestimate the theoretical effects of anatomical dissection and medical practice.[62] During his student years in Amsterdam and Leiden, Steno performed many dissections in order to "demonstrate," or bring to light, new anatomical parts and ducts, and to verify alleged discoveries claimed by colleagues. In 1661, in order to test explanations provided by Ludovic Bils regarding the movement of the chyle, he several times repeated the same experiments on live dogs in Amsterdam, "since it is not enough to have tried once to conclude something reliable."[63] At the time, in anatomy, there was nothing unusual about proving a point or dismissing an opposing hypothesis publicly. Steno, however, went one step further, when he began to cast doubt on the methods of brain dissection taught by his own teachers.[64] It is not unreasonable to claim that Steno's practice as an anatomist contributed to the critical experimentalism in terms of which he also understood Descartes' method and Descartes' requirement for "demonstration."

In any case, this critical experimentalism was of no little consequence when it came to the search for the cerebral seats of mental faculties, be it conscious

59 Roux, "Was there a Cartesian Empiricism in 1660s France?," p. 65.

60 For Steno, who read at least parts of *De augmentis et dignitate scientiae*, see Steno, *Chaos-Manuscript*, col. 24, p. 81. For Thévenot, see Roux, "Was there a Cartesian Experimentalism in 1660s France?" p. 71, note 92.

61 For Thévenot, see ibid., p. 77. For Steno, see note 28 above.

62 I thank Eric Jorink for having pointed this out to me.

63 Steno to Bartholin, 12 September 1661, in EP I, p. 142, transl. in KM, p. 392.

64 See Steno, *Discours*, p. 7, transl. in KM, pp. 509–510.

perception, imagination or memory. Indeed, Steno's refutations of the various "systems" of the Ancients, Willis and Descartes, are all based on two kinds of arguments. First, Steno argued, they appealed to anatomical descriptions that could be proven wrong in public dissection. Second, they provided "no certainty," but were unreliable, gratuitous and grounded on assertions that were not verifiable by colleagues. Under such conditions, one may wonder whether Steno's critical experimentalism did not entirely proscribe what has been called cerebral localization, or the attempt to assign corresponding brain parts to mental functions such as memory and perception. Mental functions are by definition not directly observable by a third party. How can one then verify by means of pure observation assertions about the cerebral seat of this or that mental faculty, especially at a time when a neurosurgeon could not perform an 'awake craniotomy' on a conscious patient in order to map cortical functions?

4 An Experimental Dualism?

Steno's strict experimentalism and strict definition of what is collegially demonstrable and what is not, suggests a strong epistemological separation, not to say dualism, between third-person bodily phenomena and first-person psychological functions.

Surely, mental operations somehow condition animal or human "actions," as Steno called them, i.e. sensory-motor functions, which themselves are observable. Specifically, nervous endings in the brain may shed light on the specific locations where impulsions come from or where sensory impressions end. In the *Discourse*, Steno himself said that a good way of clarifying brain functions would be to follow nervous terminations in the white substance. But he immediately added that the softness and fragility of the brain may prevent a thoroughgoing examination. Comparative anatomy[65] and vivisection may also shed new light on the location "where motion begins and sensation ends," to quote Steno's terminology in his letter to the Inquisition.[66] Accord-

65 See Steno, *Discours*, pp. 56–57, transl. in KM, p. 522: "The brain is different in different species of animals. This is another reason to examine them all. The brain of birds and fishes is very different from that of man and, in animals with a brain the closest to ours, I never saw one in which I did not find some very obvious difference. Such a difference, whatever it may be, always throws some light on the researches and may teach us that which is absolutely necessary."

66 Spinoza, *The Vatican Manuscript*, p. 10.

ing to Bartholin, the experiments conducted by Steno on fish had prompted him to localize the principle of "animal actions" in the spinal cord rather than in the brain.[67] But regardless of these experiments, two operations involved in Descartes' cerebral localizations were proscribed by Steno's critical experimentalism: first, to search for a principal seat of the soul or, in Descartes' words, for a part to which the soul was more particularly united,[68] and, second, to correlate different psychophysical functions (attention, memory, imagination, will) to different kinds of cerebral movements. This last approach requires, first, that one proceeds to a "phenomenological decomposition"[69] of the mind, or that we distinguish several kinds of mental operations on the basis of the consciousness we have of them. Next, it requires that we conceive of unobserved cerebral properties or hidden movements through which mental operations can be performed. Consider for instance how, in Descartes, the inclination of the pineal gland accounts for attentiveness, or how the small filaments of the medullar part of the brain are modified by the reiterated passage of the animal spirits, retaining in their folds the recollection of things.[70] At the very least, such explanations require that one appeals to analogy and introspection.

Steno's demanding conception of anatomy precisely prevents any localization of mental operations but also proscribes establishing connections between anatomical descriptions of cerebral parts and unobservable operations. Critical experimentalism excludes from the study of bodies any property of matter that is not fully actualized in an observable quality or a local movement. Such a restriction could appear to rely on an identification of the body with mere extension (*res extensa*), but this is not necessarily the case. Steno's demanding conception of anatomical science does however imply a mechanistic conception of matter and a strong separation between what pertains to the experimental science of bodies and what belongs to introspection and conscious first-person experience. Hence, the epistemology underlying Steno's cri-

67 See Bartholin, *Anatome ex omnium veterum Recentiorumque Observationibus Inmprimis Institutionibus b.m. parentis caspari Bartholini ad Circulationem harvejenam et vasa lymphatica quartum renovate* (1673), Book III, p. 477.

68 See Descartes, *Passions de l'âme*, AT XI, p. 351.

69 See Bechtel, "Decomposing the Mind-Brain: a Long-Term Pursuit," pp. 229–242, and esp. 231: "[The] attempt of faculty psychology to differentiate different faculties of mind is an exercise in phenomenal decomposition." See also p. 230 regarding to objection put forward by by Uttal according to which "many mental entities turn out on close inspection to be hypothetical constructs whose reality is impossible to validate because of the intrinsic inaccessibility of mental processes."

70 Descartes, *L'Homme*, AT XI, p. 179.

tique of the Cartesian conception of the pineal gland bars him from proposing any psychophysical hypotheses about the specific cerebral conditions pertaining to different mental faculties.

A manuscript written, it seems, nearly twenty years after the *Discourse* confirms that the absence of cerebral localization in Steno, stemming from the strict definition of the object of anatomy, is itself related to a strict dichotomy between *res extensa* and *res non-extensa*. The manuscript in question was found in Florence among some theological papers. It was written in Hamburg, probably in 1684.[71] It should be interpreted with caution: it contains *lacunae* and mixes physiological with normative remarks. For instance, in the middle of the text, Steno suddenly wrote, somewhat out of context, that in Spinoza there is only the study of truth and not of virtue. The aim of the paper was, it seems, to prove the existence of a non-extended intermediary between sensory and motor nerves. What matters to us is the point of departure of the demonstration which mirrors the methodological requirements set forth in the *Discourse on the Anatomy of the Brain*. Steno began by providing physiological data restricted to third-person observations and experiments, including the distinction between, on the one hand, sensory nervous filaments through which sensations are, partly at least, communicated to what Steno called the inside (*introrsum*), i.e. the white substance and the medullary substance of the brain, and, on the other hand, motor nervous filaments that communicate movement to the muscles from the inside. All these filaments extend from the peripheral organs or "extremities" toward the spinal cord and the brain.[72]

Thus, Steno did not begin by providing psychological distinctions between faculties, which he could then go on to relate to the different areas of the brain. He took his point of departure in observable *stimuli*, emitted and received, by

71 I follow Scherz, the editor of the manuscript (see EP II, p. 949). The manuscript can be found in the *Biblioteca Nazionale Centrale di Firenze*, Gal. 291, fol. 88–90. An English translation from the Latin by E. Collins and P. Maquet can be found in Kardel, *Steno. Life. Science. Philosophy*, pp. 147–151.

72 See EP II, p. 949, transl. in Kardel, *Steno. Life. Science. Philosophy*, pp. 147–148: "Certum est motus et sensus peragi in animalibus ex parte per filamenta nervorum, quorum alia extremitas introrsum continuatur versus substantiam albam cerebri et medullae spinalis, altera extrorsum fertur ad varias partes. Certum est filament nervorum, per quae sensiblium objectorum impulsus introrsum communicator, alia esse a filamentis, per quae determinationes motuum ab intra musculis communicantur. […] Certum ad eosdem impulsus ab exta fieri diversissimas mutationes determinationum ab intra. Certum est ad diversos impulsus ab extra saepius fieri easdem determinationes ab intra." In this context, "determinationes" probably means the directions (or changes of direction) of a motion.

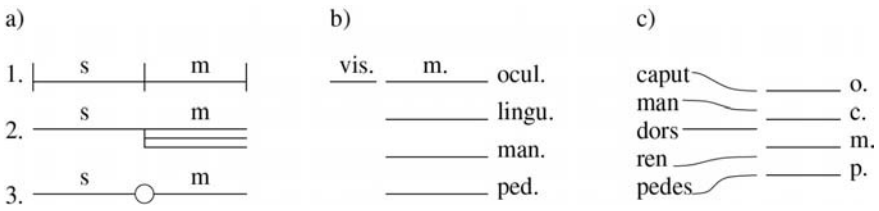

FIGURE 4.1 *From Nicolai Stenonis,* Epistolae, *II, p. 950, addiment. 24*

the human body. The core of the demonstration is the following. We know that similar sensory impulses from the outside do not necessarily determine the motor-nerves from the inside in the same way. Various sensory impulses can lead to the same motor response and, conversely, a single sensory impulse may prompt different motor responses. How to account for the fact that the two kinds of nervous filaments are physically connected in such variable and complex ways? It is not possible to imagine a one-to-one connection between them, for instance, nor can some intermediary fluid explain multiple motor responses to a single sensory impulse.

Steno gave as an example the transmission of a single musical note depicted on paper through the ocular nerves. The signal can then trigger various responses, "through the nerves to the tongue, whenever it can sing an octave above or below, through the nerves to the individual fingers with which it can strike the same note [at every] octave, and also to the feet."[73] Steno provided diagrams, without however commenting upon them.

Diagram a) shows that if the intermediary between sensory nerve (*s*) and motor nerve (*m*) were solid or fluid, then a single sensory impulse would be always followed by the same motor response or same set of motor responses. Diagram b) shows that the sight (*vis.*) of the same musical note may trigger various motor responses: various motions (*m*) of the eyes (*oculorum*), of the tongue (*linguae*), of the hands (*manuum*) or of the feet (*pedum*). Conversely, diagram c) shows how various sensory impulses can trigger the same set of motor responses: wherever someone is burned, be it on the head (*caput*), hand (*man.*), back (*dors*), waist (?—'*ren*'), or feet (*pedes*), it will trigger the same kind of motor response: the eye muscles will move (*o.*), the vocal chords will produce

73 EP II, p. 950, transl. in Kardel, *Steno. Life. Science. Philosophy*, pp. 148–149 (translation modified): "Eadem nota musica per nervos oculorum communicando fili impulsum introrsum infinitas determinationum ab intra mutations producit, per nervos ad linguam, quoties supra vel infra octavam ejus potest intonare, per nervos ad singulos digitos, quibus eandem per singulas octavas percutare potest, item et versus pedes."

a yell of pain (*c*. for *'clamor'*), and the hands (*m*.) will move to remove the pain or the feet (*p*.) will run away.

Stenon finally arrived at the following conclusion:

> This intermediary of mine, between senses and nerves of movement, perceiving and [determining] movement, cannot be [extended], otherwise each nerve would have its own corresponding point and an impulse of the same nerves would always result in the motion of the same corresponding muscle [...].[74]

Steno's reasoning rests on the restriction of material properties to extension and, as a consequence of this, the restriction of bodily modifications to the visible effects of local impulses.

It is a striking fact that Steno limited himself to third-person data and that, from those, he infered the existence of something that is precisely not physical but goes beyond the experimental query. According to Steno's critical experimentalism, such a non-extended thing cannot be associated with a specific seat in the brain. When we summarize these various elements, they add up to the following, somewhat paradoxical, situation: 1) Steno's anatomy, which rejects Descartes' conception of the human body, leads to epistemological dualism; 2) this dualism was at least once, namely in the manuscript of Hamburg, stated in Descartes' terminology, where Steno assimilated matter and extension; 3) this assimilation led Steno to affirm that some immaterial and perceiving thing must account for the connection between sensations and motions in human body; 4) but this assimilation also implied rejecting all anatomical localization of the seat of the soul or of the various mental faculties.

By restricting his intentions to what he deemed "demonstrable," Steno proposed a strictly behaviorist approach to the cerebral links between sensations and movements, contrary to all his contemporaries, who rather sought to correlate their cerebral physiology with a division into mental faculties partly based on introspection. The demonstration of a non-extended intermediary between sensory and motor nerve endings cannot, in Steno, be combined with the anatomical localization of such an intermediary somewhere in the brain.

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74 See EP II, p. 950, transl. in Kardel, *Steno. Life. Science. Philosophy*, p. 149 (translation modified): "Illud mei medium inter sensus et nervos motus, percipiens et determinans motus, non potest esse extensum, alias singuli nervi haberent suum sibi respiciens punctum et semper ad eorundem nervorum impulsum sequeretur idem respondentis musculi motus [...]."

For not only is this intermediary in itself and by definition non localizable, but Steno's experimentalism moreover prohibits any possible specification of a zone or part of the brain to which this intermediary would be particularly attached.

In turn, the impossibility of situating the seat of the mind, or the seats of mental faculties, in any specific part or parts of the brain is derived from the idea of a strict dualism between, on the one hand, *extended* observable fluids and solids endowed with local movement and modified through mechanical impulse and, on the other hand, a *non-extended* "I" that perceives and gathers sensory impulses and then selects and determines motor impulses.

4 Conclusion

We have identified in Steno a "critical experimentalism," which requires restricting experimental enquiry to the sensible properties of fluids and solids moved by local impulse, adopting an analytical approach to complex *explananda*, and submitting procedures and results to collegial verification. Such experimentalism involves a strict distinction between observable extended bodies and non-extended things lying beyond the limits of science. This dualism, implied in Steno's use of the Cartesian notion of extension in 1684, also entailed proscribing premature cartographies of the brain's cognitive functions of the kind found in the systems of the Ancients, in Willis or in Descartes. Thus, Steno's anatomy brought him to embrace a dualism that clashed with the Cartesian anthropology. This dualism highlights the difficulties in combining an experimental approach to the science of living bodies, conceived on the model of mechanics, with an explanation of the mind's functions in terms of a cartography of the brain. How to make the mind a legitimate object of an experimental science of the human body? How to connect a neuro-anatomy and physiology of sensori-motor functions with the elucidation of mental operations strongly related to those sensori-motor functions?

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CHAPTER 5

Steno's Critique of Descartes and Louis de La Forge's Response

Vasiliki Grigoropoulou

1 Introduction

The relationship between body and mind was one of the crucial questions in the philosophy of Descartes. It has been an object of continuous debate and of many different interpretations from the 17th century to our days. In his *Meditations*, priority is given to the mind—the famous *cogito* completely distinct from body. Descartes' fame is closely related to this work in which he presents his argument regarding the power of the mind to perceive and conceive things on its own. Before writing the *Meditations*, however, in the period from mid-1629 to 1633, he was working on *L'Homme*, a work exclusively focused on body. This book, along with *Le Monde*, remained unpublished until his death. *L'Homme* was published for the first time in 1662 in a Latin translation by Florent Schuyl, professor of philosophy in Leiden.[1] The French edition appeared two years later, in 1664, including a preface by Claude Clerselier and the lengthy *Remarques* by Louis de La Forge.[2] Schuyl's preface, *Ad lectorem*, emphasized the way in which Descartes' physics explained the human body anatomically, and especially the brain, without any reference to the mind. Clerselier, for his part, underlined the distinction between body and mind in *L'Homme*. In La Forge's reading, the ultimate aim of Descartes' work had been to explain the union of body and mind.[3] Hence, from the very beginning, among Descartes' editors and commentators, there was disagreement as to the metaphysical implications of Descartes' anatomy, and especially the anatomy of the brain. In this article, taking a closer look at the first reception of *L'Homme*, I want to focus on Steno's critique of the Cartesian hypotheses concerning body and the human

1 Descartes, *De Homine figuris et latinitate donatus a Florentio Schuyl* (1662).

2 Descartes, *L'Homme de René Descartes et la formation du fœtus*; *ou Traité de la lumière du meme auteur, avec les remarques de Louis de la Forge* (1st ed. 1664; 2nd ed. 1677). I use the second edition.

3 See Kolesnik-Antoine, "Les voies du corps. Schuyl, Clerselier, et La Forge lecteurs de *l'Homme* de Descartes," pp. 119–121.

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brain in *L'Homme*, as well as on La Forge's response to Steno. Descartes' theory has failed, of course. In a sense, there is no debate whether Steno's criticism of Descartes was justified. Yet, as we shall see, Descartes' work stimulated Steno to continue his research in anatomy, searching out the defects in Descartes' theory.

In the following, I will first provide a short summary of the theses advanced in *L'Homme* concerning the structure of the human brain and its role in the production of ideas, especially the so-called "corporeal" ideas. Next, I shall discuss Steno's 1665 lecture in Paris, the *Discours sur l'anatomie du cerveau*,[4] in which he challenged some basic theses in Descartes regarding the structure of the brain. Steno did not object to Descartes' theory of the distinction between body and mind. In fact, he subscribed to the mechanistic Cartesian approach to the human body and brain. Nevertheless, he made use of his new method in anatomy and his various findings to refute the Cartesian reconstruction of the brain, in particular with regard to the position and the function of the pineal gland. This refutation, however, also threatened Descartes' metaphysical hypotheses regarding the unity of body and mind, and the mind's power of perception. Therefore, Steno concluded, a new theory was required to explain the relationship between body and mind and to account for the faculty of perception.[5]

Next, I will turn to Louis de La Forge and his defense of the Cartesian theory. Descartes never attempted to verify empirically his hypothesis concerning the pineal gland.[6] Steno was a celebrated anatomist. This lent considerably weight to Steno's objections. La Forge, however, was an educated doctor of medicine with expert knowledge of the brain's anatomy. For this reason, his vigorous defense of Descartes' theory and rejoinders to Steno's argumentation are of particular interest. Already in the "Remarques," written for the French edition of *L'Homme*,[7] La Forge took issue with the objections raised by Thomas Bartholin, Steno's professor, concerning the role and function of the pineal

4 Steno, *Discours sur l'anatomie du cerveau*, new ed. by R. Andrault; English translation by G. Schertz, in *Steno's Lecture on the Anatomy of the Brain*.

5 In his *Ethics*, Spinoza rejects Descartes' hypothesis of the pineal gland. He supports the body–mind union just like Descartes did but proposes a new theory to explain it. Spinoza's library includes Thomas Bartholin's *Institutiones anatomiæ* of 1651. He probably knew of Bartholin's critique of Descartes. Spinoza knew Steno in Leiden and his library contains some of Steno's works. He may have known Steno's *Discours*. See Andrault, "Introduction," in Steno, *Discours sur l'anatomie du cerveau*, ed. Andrault, p. 45, and in this book, *supra*, pp. 95–96.

6 See Descartes to Mersenne, 1 April 1640, AT III, p. 49.

7 La Forge, "Remarques," in Descartes, *L'Homme de René Descartes*, pp. 155–368.

gland. Later, in the *Traité de l'esprit de l'homme*,[8] he undertook to refute Steno's objections as well. In these texts, La Forge does not produce a new theory about the human brain and mind, although, in his exposition of Descartes' theory of mind, some of his formulations differed from those of orthodox Cartesian theory and terminology. He put a stronger emphasis on mind-body union than Descartes had done. La Forge underlined that, according to Descartes, ideas in the mind do not resemble the objects they represent. On Descartes' view, he argued, the forms that are imprinted on the pineal gland are only occasions for constructing ideas representing particular objects. This implied that Steno's objections concerning the pineal gland only partially addressed the Cartesian theory of the human mind and its power of perceiving particular objects.

2 Descartes' Theory of the Brain

Descartes was not an anatomist by profession. He did, however, devote many years to anatomical studies because he believed it could contribute to self-knowledge (*nosce teipsum*), i.e. to the knowledge about the human being as an entity comprised of both body and mind.[9] In my view, Descartes' revival of the Delphic precept *γνῶθι σαὐτόν*, famous from Socrates, must be interpreted in terms of ideas. From this perspective, knowing oneself means knowing the ideas present in one's mind, and knowing their origin and mode of production. Correlatively, in Descartes' *L'Homme*, the body is studied as a source of ideas.

The radical distinction between body and mind postulated by Descartes in his metaphysics was a necessary condition for studying the anatomy of body in the manner of *L'Homme*, i.e. like a mere machine. Indeed, the whole novelty of Descartes' approach, as was acknowledged by Steno, was that he provided a mechanistic account of the activities of the body and brain. How the body was constructed, what its constituent parts were and how they were linked together: these were, for Descartes, fundamental questions, essential for any attempt at explaining how the body-machine was set in motion. At the same time, Descartes maintained that body and mind comprised a single entity, two natures that formed a union and interacted.

For Descartes, the so-called "animal spirits" were central for explaining motion. They are found in the brain from where they enter into certain nerves,

8 In La Forge, *Œuvres Philosophiques*. For an English translation by D.M. Clarke, see de La Forge, *Treatise on the Human Mind*. I use this translation when quoting.

9 See Descartes to Mersenne, 15 April 1630, AT I, p. 137; see also A. Bitbol-Hespériès, "Introduction," in Descartes, *Le Monde, L'Homme*, eds. A. Bitbol-Hespériès and J.-P. Verdet, pp. xiv–xv.

causing the body's limbs to move.[10] The mind does not always intervene to set the body in motion.[11] In *L'Homme*, Descartes does not discuss the mind's power to move the body, because, here, the relationship between mind and body is examined exclusively from the viewpoint of the body. Flowing constantly from the arteries to the nerves and muscles, via the brain, animal spirits activate the entire machinery of the body. The animal spirits, which Descartes compares with the wind or a flame because of the rapidity of their motion, move from one muscle to another following the laws of nature.[12]

Descartes studied anatomy and the brain in order to explain the nature of the imagination, memory and other intellectual faculties. For Descartes, the seat of the imagination and the *sensorium communis* is in the brain, specifically in the pineal gland, where an "idea'" of a corporeal nature takes shape. Such a corporeal idea provides the occasion for the soul to sense motion, size, distance, color, and other qualities.[13] As Descartes writes: "[…] I wish to apply the term 'idea' generally to all the impressions which the spirits are able to receive as they issue from gland H [i.e. the pineal gland, see fig. 5.1 in the Appendix]."[14] These ideas, originating in the body, convey the impressions apprehended by the animal spirits and are generated by the qualities of the objects of sense. Hence, besides the ideas that depend on the power of the mind alone, as Descartes argues in his *Meditations*, there are also ideas that depend on the bodily organs and mechanisms.

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10 Descartes defines "animal spirits" as follows in *L'Homme*, AT XI, p. 129, transl. in Descartes, *The World and Other Writings*, ed. S. Gaukroger, pp. 104–105: "As for those parts of the blood that penetrate as far as the brain, they serve not only to nourish and sustain its substance, but above all to produce there a certain very fine wind, or rather a very lively and very pure flame, which is called the 'animal spirits'." Concerning "animal spirits," see also AT XI, pp. 131–132; 180, and Descartes, *Le Monde, L'Homme*, pp. 178–179, note 42.

11 AT XI, p. 137.

12 Scherz notes in Steno, *Lecture on the Anatomy of the Brain*, p. 155, note 2: "The theory of animal spirits, the spirits of the soul, (*spiritus animales*, from their seat in the brain responsible for perception, motion and thought), and of the vital spirits, the spirits of life, (*spiritus vitales*, from their seat in the heart organizing pulsation and the circulation of blood and warmth) go back to ancient times especially to Galen, but was still held, in various degrees in the 17th century. Animal spirits were pictured as fine ethereal gaseous materials which formed in the brain and were conveyed to the muscles and the sense organs through the nerves."

13 AT XI, pp. 175–177.

14 AT XI, pp. 176–177. See also fig. 5.2. Gland H is the pineal gland. See also Descartes, *Le Monde, L'Homme*, pp. 197–198, note 158, and Descartes, *Les Passions de l'âme*, art. XXXI–XXXIV, AT XI, pp. 351–355.

The body, then, is a mechanism that provides an "occasion" for the mind to have feelings and ideas. Descartes often used—there are about twelve occurrences—the expression "to occasion" (*donner l'occasion de*) when referring to the role of the body for the production of the ideas and feelings in the mind.[15] And yet he also used the vocabulary of causation in this context, implying that the body is a genuine cause of the mind's ideas, allowing for reciprocal interaction between body and mind.[16] The structure of the bodily organ, say the eye, contributes towards this, which is why it is important to study and describe it.[17] Visual perception must be explained, first, through the mechanism that links the object of the senses to the image on the retina on each eye, which is then transmitted to the brain via the optic nerves. Second, it must be explained through the form in which it is registered on gland H via the animal spirits. Descartes maintained that gland H was made of very soft material and was attached to the substance of the brain only through tiny arteries, making it extremely mobile.[18]

In *L'Homme*, Descartes often stressed that it is the mind that has sensations, not the body. In his *Meditations*, he illustrated this by means of the example of a young woman whose fingers had been surgically amputated and yet still complained of pains in those fingers. For him, this implied that "a pain in the hand is not felt insofar as the soul is in the hand, but only insofar as it is in the brain."[19] Consequently, the investigation of the brain and its relation to the soul was of central importance for explaining sensations. Yet, Descartes attributed

15 On the question of whether, for Descartes, bodies are genuine causes of sensation and perception or merely occasions, see D. Garber, "Descartes and Occasionalism," pp. 9–26; Nadler, "Descartes and Occasional Causation," pp. 35–54; Scott, "Occasionalism and Occasional Causation in Descartes' Philosophy," pp. 503–528.

16 See AT XI, p. 176: "[…] this action is that causing sensory perception of the color red, or of pleasure, or the action that I said causes sensory perception of the color white, or of pain." See also AT XI, p. 182: "[…] movements of these parts and the ideas of them can cause one another in a reciprocal fashion."

17 See AT IX, p. 152.

18 See AT IX, p. 179. At this point, La Forge noted that, apart from the arteries that support it, the pineal gland is also linked to the brain through two small nerve fibers, which are very relaxed. This correction does not question the mobility of the gland, postulated by Descartes, but it is at odds with Descartes' description of the gland according to which the gland is supported only by two small arteries with no nerve reaching as far as gland H. On this, see La Forge, "Remarques," p. 314. See also Descartes to Mersenne, 1 April 1640 and 21 April 1641, AT III, p. 49 and p. 361.

19 See Descartes, *Meditationes*, AT VII, p. 77, and *Principia*, AT IV, p. 196. See also La Forge's corporeal explication in "Remarques," p. 287.

both feelings and ideas to the mind. For Descartes, sensations and feelings are confused ideas; it is the mind that has the capacity to read and properly translate the signals coming from the body.

Descartes also posed a series of questions about how the form of some objects could be registered more distinctly than that of others, how we estimate distances, how an object is recollected by the mind, how we come to be deceived, what causes optical illusions, how passions are generated, and how alertness, sleep and dreams are to be explained. But the fundamental question concerned perception, which Descartes attempts to explain by reference to geometry. For Descartes, our thought does not have direct access to physical objects. This access is mediated through the ideas shaped by the animal spirits in the pineal gland. Natural geometry, i.e. our ability to construe and explicate the world of physical objects in terms of geometry, does however enable us to assess the dimensions of objects and formulate judgments about them.[20]

Hence, the mind has no immediate access to particular physical objects, but only to the image or impression of objects imprinted on gland H, providing the occasion for the mind to form a representation. The mind moreover has an innate capacity to form representations of objects, by means of concepts that it conceives on its own. This point was to be analyzed further by La Forge, as I shall argue in the third section of this paper. Nevertheless, judgments about particular objects cannot be formulated independently of experience, without contact with them, nor can they be explained without knowledge about how they are imprinted on the brain. In other words, judgments about particular objects cannot be formulated without "corporeal ideas."

An external stimulus, such as a word, is like a signpost giving the mind an opportunity to form a representation. It is the mind that sees, not the eye, Descartes maintains. But the mind still sees through the brain: without the impulse provided by the impressions imprinted on it, the mind would not form representations of particular physical objects. The mind senses the movement, the magnitude, the distance, the colors, the sounds, the smells and the other qualities[21] by means of the forms registered on the surface of gland H, which is thus the seat of the imagination and of the *sensorium communis*. There is, or should be, a center for focusing all the various points of information from the senses, a certain privileged point in the brain that functions as "a channel of communication between the members of the body and the soul," as La Forge

20 See AT IX, pp. 62–63.

21 Ibid., AT XI, 175.

says in his *Remarques* on Descartes' *L'Homme*.[22] That center is the gland H, which thus contributes to a uniform apprehension of external objects and of influences on the body.

The problem of the body-mind union here comes to be reformulated in terms of body-mind interaction in a privileged point. Moreover, the problem now also concerns the unity of representations of objects, insofar as they involve connections between ideas of various forms and origins. Our ideas have different sources, but they all contribute to the composition of the representation of an object. As should be clear, in order to maintain such an explanation, the question of the body-mind union and the notion that there exists a privileged point of interaction are of great importance. For this reason, as we shall see, in his commentary of Descartes' *L'Homme* and in his *Traité de l'esprit*, Louis de La Forge emphasized the union of the body and mind more than their distinction.

3 Steno's Refutation of Descartes' Theses

Nicolas Steno was not well versed in metaphysics. But his talent, indeed genius, is evident from his work on anatomy. He refutes a number of Descartes' hypotheses concerning the anatomy of the body and especially of the brain. Born in Copenhagen into a well-to-do goldsmith family with a strong puritan streak,[23] Steno completed his first studies there under Thomas Bartholin, a professor of medicine who had studied at the University of Padua.[24] Bartholin, renowned in all of Europe, had already expressed his objections to Descartes' thesis regarding the function of the pineal gland. According to Bartholin, the pineal gland could not be the center of the *sensorium communis* due to its small size which made it unsuitable for receiving the "species" or forms of objects from the senses. Moreover, as he pointed out, the nerves did not touch the pineal

22 See La Forge, "Remarques," p. 286. As Malebranche notes: "*Il suffit qu'il ait une partie principale*" (*Recherche de la Verité*, II, § 2, in *Œuvres de Malebrance*, ed. G. Rodis-Lewis, vol. I, pp. 193–194).

23 See Grell, "Between Anatomy and Religion: The Conversions to Catholicism of the Two Danish Anatomists Nicolaus Steno and Jacob Winsløw," p. 210.

24 Bartholin was famous for his *Anatomia Reformata* of 1651, where he presented a detailed account of the circulation of blood, originally a reworking of his father's *Anatomicæ institutiones corporis humani* of 1626. The work was widely used in Britain and translated into French by Du Prat in 1647.

gland.[25] According to Bartholin's scientific argumentation, there was no room for the Cartesian thesis concerning the union and interaction between body and mind.[26] Steno followed up on the work of his powerful teacher. Bartholin took notice of this outstanding and unusual student of his, who aimed at perfecting his teaching and surpassing him in dissection skill.[27]

Steno later left Copenhagen in order to improve his medical education. He studied in Amsterdam for a short period with Gerard Blasius, and later at the Univeristy of Leyden (1660–1663) under some of the leading anatomists of the day,[28] Johannes Van Horne (1620–1671) and Franz De le Boe, or Franciscus Sylvius (1614–1672). Like Bartholin, Sylvius had formulated objections to some of Descartes' basic ideas about the anatomy of the body.[29] In his *Specimen of Observation on Muscles and Glands* of 1664, Steno expressed his debt to Sylvius for his experiments, his lessons and assistance in his studies. In this work, Steno criticized the traditional conception of the role of animal spirits in relation to muscle function. He went beyond the teachings of the Galenic tradition, which were still very influential in 17th century medicine, but also beyond the teachings of his teacher, Thomas Bartholin. He explained the workings of the heart in purely mechanical terms, on the basis of careful observation and skillful anatomical research and experimentation. Incidentally, during this period, Steno met Spinoza, who took a keen interest in his dissections.[30]

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25 See Bartholin (ed.), *Anatomia, ex Caspari Bartholini parentis Institutionibus, omniumque recentiorum et propriis observationibus tertium ad sanguinis circulationem reformata*, Lib. III, Cap. vi: *De supreme cavitate seu capite*, p. 337. See also Andrault, "Introduction," p. 50, note 1.

26 See Mønster-Kjær, "Thomas Bartholin. Theological anatomy in the 17th century," p. 9. This commentator argues that, mainly because of his treatises on biblical medicine, Thomas Bartholin was seen "primarily as a theologian. For him anatomy was merely a tool, and so it had been for scientists all over Europe from its gradual evolvement as a field of study from Antiquity to the Renaissance. It had been a tool to illustrate the greatness and perfection of God's Creation in artistic ways, a tool to prove sanctity, a tool to establish causes of death in both judicial and medical contexts etc."

27 On the relationship between Bartholin and Steno, see Porter, "Thomas Bartholin (1616–80) and Niels Steensen (1638–86). Master and pupil," pp. 99–125. Porter argues that the powerful professor, Bartholin, did not favor Steno for a position at the University, since "he worried that his great reputation should be eclipsed by his brilliant young pupil" (ibid., p. 111).

28 See ibid., pp. 109–110.

29 See KM, pp. 68–69. See also Andrault, in Sténon, *Discours sur l'anatomie du cerveau*, p. 78, note 1.

30 See Steno's *Letter to the Reformer of the New Philosophy, concerning the true philosophy*.

In 1664, Steno moved to Paris, where he benefitted from the patronage of Melchisédec Thévenot, a wealthy humanist with excellent contacts to the Court of Louis XIV who provided support for a number of talented young scholars. While in Paris, Steno conducted a number of public and private anatomical dissections and presented his famous lecture *Discours sur l'anatomie du cerveau*, pronounced in 1665 and published in 1669. In 1666, he took up residence in Italy and converted to Catholicism the following year.

After having read Descartes' *De Homine* for the first time, Steno wrote, in a lengthy letter sent from Leyden to Bartholin on 21 May 1662, that, in Descartes' work, "we see figures that do not lack elegance, and which certainly are the product of a genius' brain; yet I strongly doubt that one would ever find this in any [actual] brain."[31] Steno's letters reveal that he studied Descartes' works very carefully.[32] The famous philosopher inspired him and he appeared even more fervent than Descartes at this time in his insistence on certainty and the importance of providing strict mechanical explanations of the human body. Certainly, in the *Discours sur l'anatomie du cerveau*, he objected to Descartes' description of the pineal gland. Nevertheless, the Cartesian analysis, the application of geometry to nature, and the use of doubt as a means to attain certainty, along with Descartes' conviction that the body, including the brain, was a machine that could be studied as such, exerted a profound influence on Steno. As he says in his *Discours*:

> Friends of M. Descartes, who take his Man for a machine, will no doubt be so good as to believe that I am not speaking here against his machine, the artifice of which I admire, but as for those who pretend to show that M. Descartes' man is made like other men; anatomical experience will make them see that such an attempt must be unsuccessful.[33]

This letter was written probably in April 1671 and printed in Florence in 1675. There is no doubt that it was intended for Spinoza (see EP I, pp. 231–238). As Steno writes in this famous lengthy letter, "during several days he [Spinoza] came to me every day at that time to see the anatomy of the brain which I studied in different animals in order to find the seat of the principle of movement and the ending of the sensations" (cit. in Totaro, "Documenti su Spinoza nell'Archivio del Sant'Uffizio dell'Inquisizione," p. 100).

31 EP I, p. 163 (my translation): "[…] *figurae conspiciuntur non inelegantes, quas ex ingenioso cerebro produisse certum est; an vero tales in ullo cerebro conspiciendae, valde dubitarem*".

32 Steno rejects Descartes' explanation of tears in the *Passions of the Soul*, art. 128. On this, see Steno to Bartholin, Leyden, 21 May 1662, EP I, pp. 153–155. See also Steno's work *Anatomical Observations on the Glands of the Eyes*, transl. in KM, pp. 407–416. See, finally, Olden-Jørgensen, "Nicolas Steno and René Descartes," p. 151.

33 Steno, *Discours*, p. 102, transl. in *Lecture*, p. 133.

Steno turned Cartesian doubt against Descartes himself, developing deep reservations about Descartes' anatomical teachings. And yet, as Gustav Scherz argues,[34] Descartes' anatomy of the brain was exactly what prompted him to undertake further energetic investigation. Indeed, applying the Cartesian method of doubt in the field of anatomy led him to experiment with new hypotheses and new methods of dissection. As an innovative but also methodical anatomist, Steno thus attempted to determine where the nerves of the brain begin and where they end.[35] Since, at the time, including in Descartes, nerves were considered organs of primary importance not only for locomotion but also for the senses, the empirical data he obtained using this new methodology allowed him to conclude that the Cartesian description of the brain and of the function of the pineal gland in particular could not be correct.

For Steno, Descartes' error was to believe that the pineal gland moved incessantly from side to side. On the basis of his anatomical investigations, he argued that

> experience assures us that, in fact, it is incapable of doing so, for it is obvious that it is so entangled among all the parts of the brain and so well attached to these parts on all sides, that you would not know how to give it the least movement without violence and without breaking the fibers that hold it attached.[36]

He thus denied that this gland played any privileged role and, by the same token, he rejected Descartes' thesis regarding the power of the mind to move the body, since it was predicated on the mobility of this gland. He also rejected Descartes' assertion that the gland was situated at the center of the brain "just at the entrance to its concavities."[37] Steno, by contrast, showed that "the posterior part of the gland, namely one half of it, is so much outside of the concavities that it is very easy to satisfy spectators on that point."[38]

Next, according to Descartes, blood had to flow directly from the heart to the pineal gland in order not to lose its heat. Via this flow, the animal spirits would then end up in the gland, where patterns and forms would be registered,

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34 See Scherz, "Introduction," p. 88.

35 Steno, *Lecture on the Anatomy of the Brain*, p. 125.

36 Ibid., p. 132.

37 See Descartes, *Traité de l'Homme*, in AT XI, p. 129, transl. in Descartes, *The World and Other Writings*, p. 106.

38 Steno, *Discours*, p. 96, transl. in *Lecture*, p. 130.

providing the occasion for the mind to sense and perceive sensory objects. This, however, as Steno showed, was contrary to experience.[39] As he observed, the arteries did not concentrate around the gland, since in fact there were veins returning to the heart.[40] Therefore, contrary to Descartes' theory, a "corporeal idea" could not be presented in the pineal gland, impelling the mind to form its idea of an object. The interaction of body and mind could not be explained in this way, nor could the role of the body in perception.

Steno saw that Descartes' priority had been to adapt his empirical research to his metaphysical principles. Not surprisingly, then, his refutation of Descartes' theories about the brain and the heart also induced him to question the validity of those metaphysical principles, in particular with regard to the nature of perception. As he writes to Leibniz in 1677, after his conversion to Catholicism, alluding to Descartes:

> If these gentlemen, almost universally admired by the learned, think that they have provided indubitable demonstrations regarding things that a ten-year old boy can prepare for me in an hour, so that without any use of words, but simply by observing them, they overthrow the most ingenious systems of these great minds, then what assurance can I have of other, more subtle things that they boast about? What I mean is this: If they have erred to such a degree when it comes to material things that are laid before our senses, what assurance can they give me that they are not equally mistaken when dealing with God and the soul?[41]

Reflecting on his interest in Descartes in the long letter to Johannes Sylvius, Steno even attributed his rejection of Cartesianism to divine providence, implying that God had directed him in his anatomical undertakings, making him see

39 Steno also disputes the term "animal spirits" (*esprits animaux*), arguing that it is meaningless. See Steno, *Discours*, pp. 84–85, transl. in *Lecture*, pp. 123–124.

40 See Steno, *Discours*, p. 100, transl. in *Lecture*, p. 132.

41 Stensen to Leibniz, November 1677, in EP I, p. 368 / Leibniz, A, II, I, p. 576. I use the translation in Lærke, *infra*. Steno continues: "If God reveals the errors of these great minds to me at the very time when I am admiring them most, this should not be taken as a mere coincidence but recognized as [an expression of] God's goodness. And even though I have not entirely abandoned the doctrine [of Descartes], which does contain some true things, I did however gradually feel this excessive admiration come undone, and I got to know the weakness of the human mind and the precipices toward which it is lead by presumption" (ibid.).

the error of his ways and reject the ideas of Descartes.[42] Steno, however, did not himself proceed to provide another scientific explanation of interaction and perception. Steno only asserted knowledge about things he was able to prove empirically and the nature of perception and interaction did not belong among them.[43] Indeed, for him, only "God's Logos and all His verbs were truest."[44] Hence, as Ole Peter Grell argues, "Steno appears to have moved towards his conversion via his growing doubts about what could be learnt with certainty about the created world from anatomical dissections."[45]

The story would have been different, of course, if Steno had been better versed in metaphysics than he was in natural philosophy and theology. As Leibniz writes in a letter of November 1677:

> Far from reproaching Stensen, I can say that I appreciate him, yes, if I may say so, I like him. Indeed, I recognize in him a zeal that is animated by a veritable charity. I do not wonder about his aversion against philosophy because he has not yet experienced the power of metaphysical proofs.[46]

Steno's anatomy investigations both furthered and helped demolish the mathematical and mechanical study of bodies. Steno subscribed to Descartes' mathematical and mechanical study of nature. And yet, as Sebastian Olden-Jørgensen has argued, Steno also provoked a Kuhnian "crisis" and opened the way to a "new paradigm"[47] when challenging Descartes' physiology and mind-body theory. As we shall see in the next section, Louis de La Forge, on the contrary, undertook to defend it and reverse the tide.

4 La Forge's Refutation of Bartholin's and Steno's Refutations

Steno presented his findings publicly in Paris in 1665. In the October the same year he went to Saumur to visit Louis de La Forge, doctor in medicine. Early November, La Forge finished his work *Traité de l'esprit de l'homme*, which

42 See Steno to J. Sylvius, 12 January 1672, in EP I, pp. 257–260.

43 Troel Kardel sees Steno as a precursor of Karl Popper in his monograph, *Steno: Life, Science, Philosophy*. See also the remarks of Jole Shackelford in his review of this book in the *Bulletin of the History of Medicine*, pp. 342–343.

44 See Steno to Johann Brunsmand, November 1673, in EP I, p. 290.

45 Grell, "Between Anatomy and Religion," p. 220.

46 EP II, p. 931.

47 Olden-Jørgensen, "Nicolas Steno and René Descartes," p. 156.

contains a criticism of Steno's argumentation against Descartes.[48] La Forge had however discussed similar issues earlier on, in his "remarks" included in the French edition of Descartes' *L'Homme*, published in 1664. As Claude Clerselier recounts in his lengthy preface to *L'Homme*, when preparing the edition for publication, he found that the diagrams of the brain in the Latin edition by Schuyl did not fit with Descartes' text. He therefore looked for someone who could provide him with accurate diagrams of the brain. His choice fell quite naturally on Louis de La Forge who had expert knowledge of the anatomy of the brain as well as of Descartes' work. As Clerselier recounts in the introduction to the treatise, La Forge went about the task with diligence, writing an extended commentary that was appended to the edition.[49] In this commentary, La Forge took into account the work and critique of Descartes by Steno's teacher, Thomas Bartholin. Now, Steno mainly studied the Latin edition of Descartes' *L'Homme*, which appeared in 1662. But he also read La Forge's long commentary in the 1664 Clerselier edition. Therefore, in the *Discours*, Steno criticized not only Descartes but also La Forge's *Remarques*.[50] After meeting with Steno in 1665, La Forge published his *Traité de l'esprit*, in which, it seems, he responded to Steno's objection to Descartes and to himself, although he does not mention Steno by name.[51] Let us consider more closely this set of texts from La Forge's perspective.

In his *Remarques* and later, in the *Traité*, La Forge gave detailed expositions of Descartes' philosophy, developing it further, supplementing it and giving

48 See Clair, "Biographie," in La Forge, *Œuvres Philosophiques*, p. 60.

49 In his edition of *L'Homme*, Clerselier decided to include the diagrams of the anatomist and mathematician Gutschoven, which are indicated with the letter G (see fig. 5.3), along with the drawings by De La Forge, indicated by the letter F.

50 In the *Discours*, Steno refutes an assertion by La Forge according to which "there is no doubt that it [the generation of spirits] takes place primarily in the ventricles of the brain, around this little gland, which is called *Glandula pini* and which is suspended, or rather supported, as if in the air, between the third and the fourth ventricle, by an infinity of small arteries that release their spirits into it" (see La Forge, "Remarques," p. 192). Steno objected that "since it has been made so skillfully, you will observe the posterior part of the gland quite uncovered, without any visible passage by which air or other fluid might enter the ventricles" (Steno, *Discours*, p. 97, transl. in *Lecture*, p. 130).

51 See note by R. Andrault in Steno, *Discours*, p. 98, note 1. The work by La Forge was printed on 5 November 1665, only a month after his meeting with Steno, at a time when the *Lecture* was not yet published. It is possible that Steno gave to him a copy of the lecture during their meeting in Saumur, or someone else did, maybe Clerselier. It is beyond doubt that La Forge knew Steno's objections.

it additional support. To better grasp La Forge's position, we must, then, first return to the source, i.e. to Descartes himself. Descartes' *L'Homme* begins as follows:

> These men will be composed, as we are, of a soul and a body. And I must describe for you first the body on its own; and then the soul, again on its own; and finally I must show you how these two natures would have to be joined and united so as to constitute men resembling us.[52]

The work focuses on the anatomy of the body and especially of the brain. Yet, Descartes' entire project is oriented toward explaining the body-mind union. This was what Descartes intended to explain when pointing to the pineal gland as the principal seat of the soul, as the organ of the *sensorium communis* and of the imagination. The notion of corporeal ideas also contributes to the argumentation concerning the body-mind union. In this respect, Descartes' sharply contrasted with the authoritative work of Thomas Bartholin and his father, Caspar Bartholin. Hence, in his *Institutiones Anatomicæ corporis humani* of 1626, Caspar Bartholin explained how anthropology, the *doctrina de Homine*, had two parts: anatomy, dealing with the body and its parts, and psychology, dealing with the soul.[53] Consequently, anatomy, i.e. the science of body, should not concern itself with questions about the soul. Anatomy and psychology did however have in common to be equally grounded in theology. Thus, in the work of the Bartholins, both father and son, anatomy was a way of fusing natural philosophy with the search for God, an area where physics and theology could possibly unite.[54]

I shall now consider in more detail La Forge's reponses to Bartholin and Steno, in the *Remarques* and in *Traité de l'homme*, Chapter 10, entitled "Corporeal species, and Intellectual Ideas or Notions."[55] In his *Anatomia reformata*

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52 AT XI, p. 119, transl. in Descartes, *The World and Other Writings*, p. 99.

53 Bartholin, *Institutiones Anatomicæ Corporis Humani*, p. 1: "*Anthropologia seu doctrina de Homine vulgò, & recte tamen in geminas dispescitur partes: Anatomiam, quæ de corpore ejusque partibus agit, & ψυχολογία, quæ de anima.*"

54 See Bartholin, *On Diseases in the Bible. A Medical Miscellany* (*1672*). This work especially indicates the connection between natural philosophy and theology.

55 See La Forge, *Treatise*, pp. 77–97; La Forge, *Traité de l'esprit*, in *Œuvres Philosophiques*, pp. 157–182. Note that, in the *Remarques*, La Forge uses the term "corporeal idea" as employed by Descartes, whereas in the *Traité de l'esprit*, he replaces it with the term "corporeal species." The notion harks back to the scholastic language of species, but La Forge uses it in order to avoid confusion with ideas of the mind in Descartes.

of 1651, Bartholin objected to Descartes that "[the pineal gland] is an extremely small body, and far too obscure, to represent the forms of all things clearly."[56] In the *Remarques*, La Forge responded as follows to this criticism: "As small as it may be, it will always have points and holes, so that we can receive different impressions at the same time. Since it is very small, it will be more capable of receiving them and of stirring, so that it may give occasion to the soul to perceive them".[57] The small size of the pineal gland, therefore, cannot invalidate the Cartesian theory about it. Next, Bartholin objected to Descartes that the nerves did not touch the pineal gland. Consequently, the "species," i.e. Descartes' corporeal ideas, could not be transferred via the nerves. This objection, stronger than the first, was based on anatomical data. When replying, La Forge insisted that the pineal gland "is attached to the rest of the brain by only two nervous filaments, as indeed Sylvius remarks, […] so that it can move to one side or to the other, following to the pressure it receives from the animal spirits."[58] The gland, La Forge argued, is so delicate that it cannot pose any resistance to the course of the animal spirits. And it does not matter that the pineal gland is not touched directly by the nerves. In fact, this makes it more mobile, so that the impressions of objects will come out less confused.[59] We note how, in both his replies to Bartholin, La Forge rebutted his adversary on the terrain and with the weapons of the latter, namely anatomical arguments based on observation.

In the *Traité de l'esprit*, Bartholin once again figured as one of La Forge's opponents. Bartholin had objected to Descartes that the eyes receive the species of the sensible objects in a confused way.[60] For La Forge, however, Bartholin's mistake was to believe that sensible species were like little tapestry paintings at the back of the brain—a mistake made by many other authors as well.[61] It was wrong to think, La Forge writes, that the mind "contemplates the species

56 Bartholin, *Anatomia Reformata*, p. 337: "*Nam nimis exile corpus, & obscurum quam clarè omninum rerum species repræsentet.*" Quoted in La Forge, "Remarques," p. 288.

57 La Forge, "Remarques," p. 282.

58 Ibid., p. 283: "[…] elle n'est attachée au reste du cerveau, que par ces deux filamens nerveux qu'a remarquée Sylvius […] [et que le reste de son corps] peut très facilement être porté de coté ou d'autre […]".

59 Ibid., p. 289.

60 Bartholin, *Anatomia reformata*, p. 337: "*Oculus quidem etiam minimus sive confusion species recipit.*"

61 La Forge, "Remarques," p. 291. The main adversary of the *Treatise* was however Hobbes and in particular Hobbes' critique of Descartes in the *Third Objections*. La Forge also discussed and criticized Pierre Chanet and the famous physician Fracastoro. Hence, La Forge strongly criticizes Chanet's understanding of "the 'species' of imagination as

which come to it from objects, like so many little pictures which represent to it everything going on outside, almost like a man who is looking in a mirror"[62] and "most of these species are not images, paintings or pictures of the objects of which they give us a thought."[63] In fact, La Forge argued, "the corporeal species are just the changes which objects […] cause in the motion and configuration of the flow of spirits which exit from the pineal gland."[64] The corporeal species stimulate ideas in the mind but do not resemble the objects they correspond to, no more than the ideas in the mind resemble corporeal species. The belief in their similarity is a prejudice from which we are able to liberate ourselves to the extent that we acknowledge the difference between corporeal species and the ideas in the mind. Thus, contrary to what the scholastic tradition affirmed, La Forge argued, we do not perceive objects in virtue of a similarity relation but the corporeal species is the occasion for the mind to form its ideas.[65] In this way, La Forge interpreted the impressions, that is to say the corporeal species, in terms of motion, seeing them as merely occasional causes for mental ideas. By the same token, he ended up defending a form of parallelism between body and mind, suggesting correspondence rather than causation between bodily motions and thoughts in the mind. As he writes: "I must set the mind here in parallel with the body. Although these two substances have completely different essences, nevertheless the properties which belong to each of them are related to them in the same way."[66]

La Forge maintained the essential distinction between body and mind, since the mind could not be reduced to matter or understood through it. But his parallelist theory strengthened the Cartesian argumentation when it came to the relationship between the body and the mind, giving a better grasp of their union. La Forge, on that point, would go further than Descartes and argue that "human beings should not consider themselves pure spirits in this life, but substances composed of a mind and body (on which the mind depends in most

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pictures, of animal spirits as the light which makes them visible, and finally of the soul as a spectator who looks at them" (ibid., p. 85). For Fracastoro as well, La Forge argued, "the human mind does not contemplate any species other than the little images which it thinks external objects send to our senses and imagination" (ibid., p. 78).

62 La Forge, *Treatise*, p. 78. See also La Forge, *Traité de l'esprit*, in *Œuvres Philosophiques*, p. 159.

63 La Forge, *Treatise*, p. 79.

64 Ibid., p. 83.

65 See La Forge, *Treatise*, p. 79: "[…] most of these species are not images, paintings or pictures of the objects of which they give us a thought."

66 Ibid., p. 90.

of its operations)."[67] Moreover, he tried to confirm Descartes' claim that the human mind, with regard to its powers, was "like a part of the divine mind."[68] Descartes only stated, La Forge argues, that the mind is *like* a part of the divine brain, or that the human mind *is similar to* God's mind. This is because the human mind, like God's, need not form its ideas on the basis of a similarity to physical objects. In fact, the mind represents everything through ideas that have been produced by the mind itself. Bodies are only "remote and occasional causes which, by the union of mind and body, cause our faculty to think and determine it to produce the ideas of which the faculty of thinking itself is the principal and effective cause."[69] La Forge thus attempted to strengthen Descartes' argument about the power of the mind while also stressing the role of body-mind unity in perception, insofar as bodies and corporeal species are occasional causes—conceived as inferior but still real causes—of the mind's ideas. Thus, for him, the clarity of ideas depended on the power of the mind, not on any similarity with corporeal species.[70] However, even though corporeal species are seen as remote and inferior causes, they still provide the mind with an occasion to form ideas of particular things. Accordingly, contesting the existence of these corporeal species would cast doubt on the explanation of ideas in the mind, at least in part.

In the *Traité de l'esprit*, La Forge also attempted to defend Descartes' hypothesis on the pineal gland and in Chapter 15 he discussed Steno's objections without naming him. First, he responded to Steno's objection that there is nothing unique about the pineal gland.[71] Agreeing with Descartes, La Forge maintained that there is a single gland while other parts of the brain are duplicated.[72] Secondly, as will be recalled, Descartes had maintained that the pineal gland was situated "approximately at the center of the brain's substance, right at the entrance to its concavities."[73] Steno had objected that the gland was in fact sit-

67 Ibid., p. 211.

68 Ibid., p. 91.

69 Ibid., p. 92.

70 See La Forge, "Remarques," pp. 288–289.

71 See Steno, *Discours*, p. 109, transl. in *Lecture*, p. 138: "We say that there are two glands in the brain though we do not know if one or the other has anything in common with glands apart from shape."

72 See Descartes to Meyssonnier, 29 January 1640, AT III, p. 19, where Descartes argues that the little gland called *conarion* is the principal seat of the soul and the place in which all our thoughts are formed, since this is the only part of the brain which is not duplicated. See also La Forge, *Treatise*, p. 141.

73 AT XI, p. 129.

uated "outside of the concavities." La Forge here replied on Descartes' behalf that this result only came about because Steno had adopted a different method of dissection,[74] arguing that, on Steno's technique "the third ventricle which is behind it is not visible yet and the fourth, which descends into the cerebellum, cannot be seen in this position."[75] Hence, La Forge was familiar with Steno's anatomical technique and disputed its validity. This point is crucial, because for Steno only anatomical method could prevent error.[76]

Thirdly, La Forge responded—with a trace of irony—to the objection that the gland is not flexible: "[…] if they can convince us that all the parts of a living animal's brain are as compacted as those of the head of a dead calf, their objection may be acceptable and we possibly agree with it."[77]

Finally, La Forge responded to Steno's contention that the pineal gland is not in the source of animal spirits. Steno had denied this partly by arguing that he found no evidence that there existed any such thing as "animal spirits" and, moreover, that the gland was not surrounded by arteries. Quite to the contrary, Steno held, "veins and not arteries transmit the blood towards the heart, whereas the arteries convey it from the heart to the brain."[78] Against this, La Forge maintained the existence of animal spirits, identifying them as the "more subtle parts of the blood." He answered the argument regarding the absence of arteries as follows:

> [One] should not deny that this gland is located at the source of animal spirits because some vein is possibly observed among the arteries of the choroid plexus. On the contrary, the mixture of these two types of duct is a sign of a special development and it shows that, in this location, the larger parts of the blood are separated from the more subtle parts.[79]

74 Steno, *Discours*, p. 98, transl. in *Lecture*, p. 131.

75 La Forge, *Treatise*, p. 142.

76 It is implied that the science of body, i.e. physiology, emerges from the observation of facts, which was a widespread belief in the medicine of 17th century. Yet, there was less agreement about what those facts were. See Guerrini, "Experiments, Causation, and the Uses of Vivisection in the First Half of the Seventeenth Century," pp. 227–254.

77 La Forge, *Treatise*, p. 142.

78 Steno, *Discours*, p. 100.

79 La Forge, *Treatise*, p. 142.

5 Conclusion

Descartes himself had not provided empirical evidence for his claims regarding the pineal gland. Nonetheless, he never went back on the hypothesis, since abandoning it would require introducing a new theory of perception and a new conception of the relationship between mind and body. It was in this breach that Steno's work on the anatomy was inserted, to the detriment of Descartes' conception of the mind-body union. In his works on anatomy, Steno followed the teaching of Bartholin, separating this discipline from psychology, that is, from the study of the soul. Contrary to this, when defending Descartes' theory, La Forge conceived of another kind of anthropology in which the science of body remained closely related to the science of mind. In doing this, La Forge did not introduce any new theory. But he provided additional support for Descartes' optimism regarding the mind as an active causal power[80] and regarding the body as a source of ideas, without taking recourse to divine grace as an explanatory tool. La Forge nevertheless recognized that none of it was established as demonstrably true, but only that it represented the "most probable and most intelligible hypothesis among all those which have so far been introduced to explain all animal functions".[81]

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80 On this, see Nadler, "Louis de La Forge and the Development of Occasionalism," pp. 215–231.

81 La Forge, *Treatise*, p. 142.

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Appendix

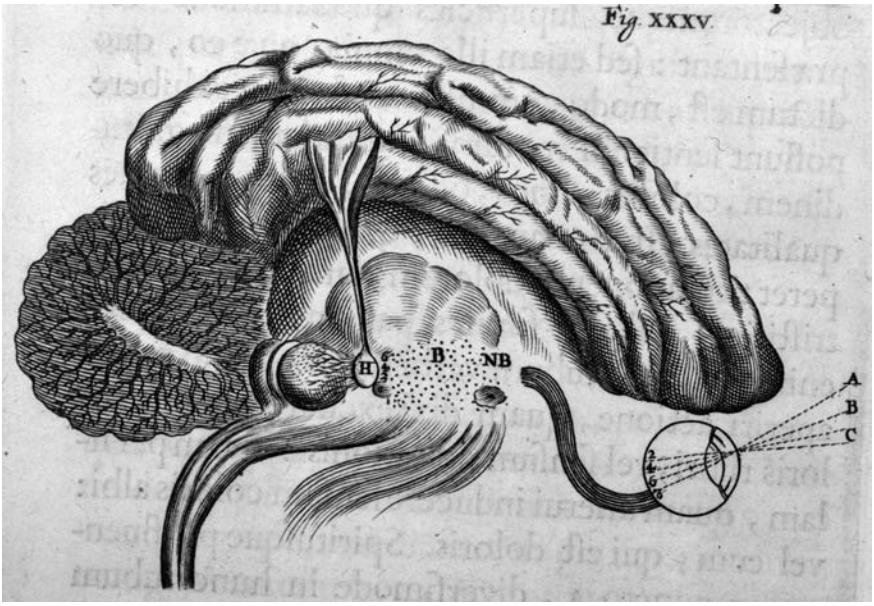

FIGURE 5.1 *Design for the function of the brain in Descartes'* De Homine*—H refers to the pineal gland*

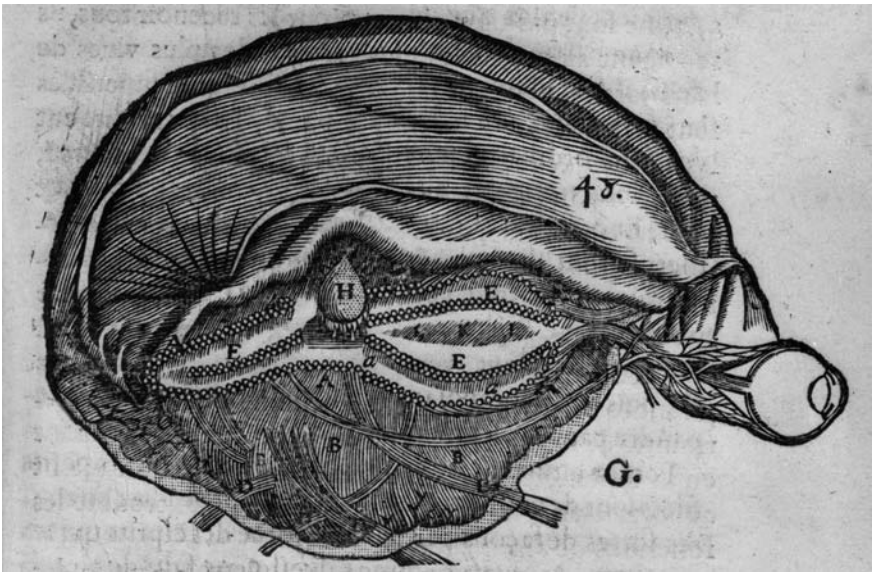

FIGURE 5.2 *Design for the function of the brain in Descartes'* De Homine*—H refers to the pineal gland*

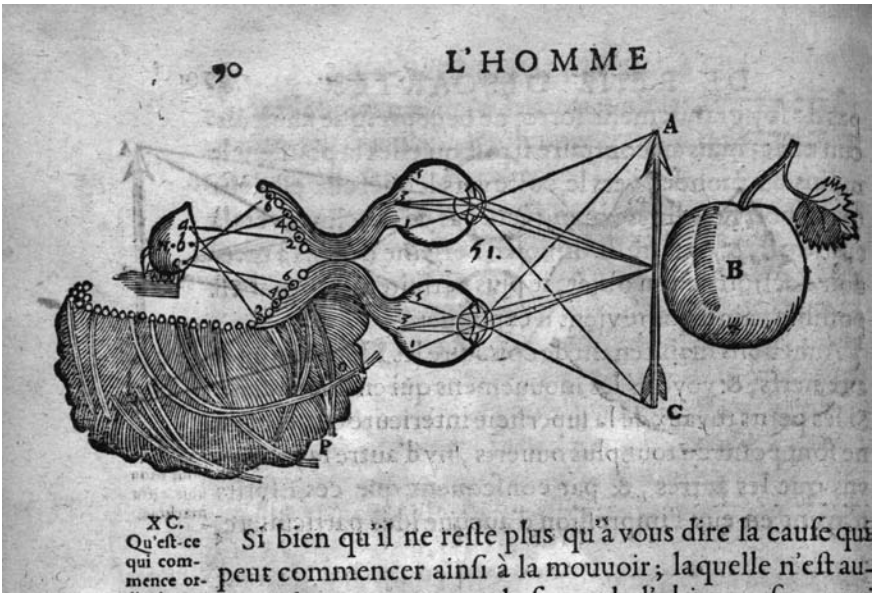

FIGURE 5.3 *Gutschoven's diagram of the human brain in Clerselier's edition of Descartes'* L'Homme

FIGURE 5.4 *Bartholin's diagram of the human brain in* Anatomia reformata—*K refering to the pineal gland*

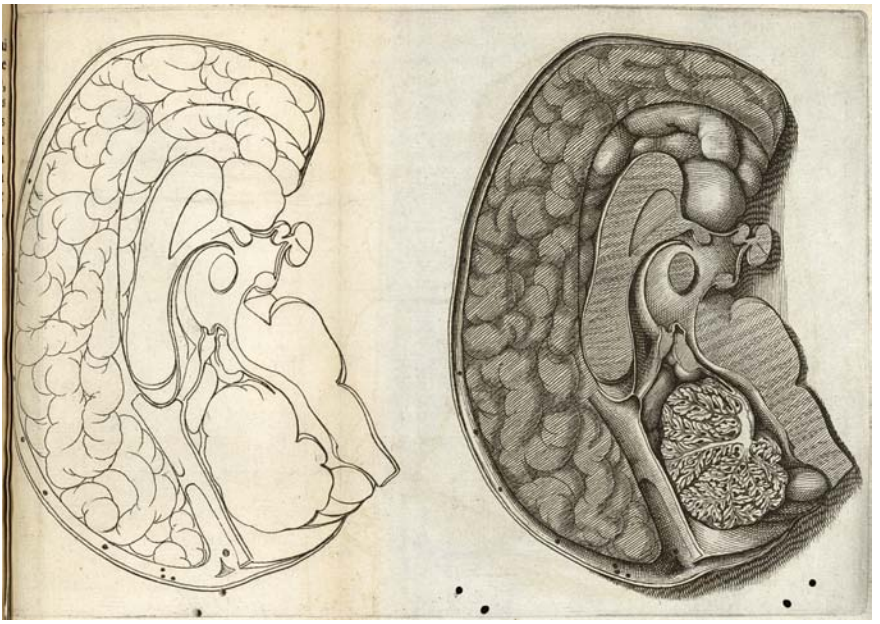

FIGURE 5.5 *Steno's drawings of the human brain in* Discours sur l'anatomie du cerveau

CHAPTER 6

Steno's Myology: The Right Theory at the Wrong Time

Troels Kardel

1 Introduction

The *Elementorum myologiæ specimen seu musculi descriptio geometrica*,[1] completed and published in Florence in 1667, was the third and main work on muscle contraction by Nicolas Steno.[2] It included a letter in which the author thanked his host and benefactor in Paris, Melchisédec Thévenot, for his hospitality and for having procured for Steno the favor and affection of his friends, including Steno's new benefactor, the Grand Duke of Tuscany, Ferdinand II. In the letter, Steno also told Thévenot that the reception in Florence of his "new system of muscle" had not been smooth:

> There is no need to borrow arguments from Orators to prove that sweating over this work is not the doing of a man who often spends his leisure time in the presence of famous men, as my critics have not been ashamed to assert [...]. It deals with the motor fibre; with the part that moves the limbs, that breathes the air, that moves the blood—in short, it deals with that upon which depend the signs of life and death. But who will call idle the desire to explore the nature of a part which, so far, remains almost unknown and see what can be accomplished by this exploration? But such considerations escape our critics. [...] You as well as I remember the objection: What is the use of wanting to know? What practical application does it have? So by repeating their questions again and again, adorned

1 I use the following additional abbreviation: SOM = Stensen, *Steno on Muscles*, ed. T. Kardel, transl. M.E. Collins and P. Maquet.

2 For the three works (in order of writing), see N. Steno, *Nova musculorum & cordis fabrica* in Thomæ Bartholini, *Epist. Medicin. Cent. IV* (1667), Epist. LXX, pp. 414–421, facs. and transl. in SOM, pp. 58–75; *De musculis & glandulis observationum specimen* (1664), transl. in KM, pp. 463–477; and, third and finally, *Elementorum myologiæ specimen seu musculi descriptio geometrica* (1667), facsimile and transl. in SOM, pp. 76–228.

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> with various figures of speech, they try to make those who remain ceaselessly alert to new discoveries, appear ridiculous, I may even say troublesome.[3]

Steno's unnamed adversary in the Florentine *Accademia del Cimento* was probably Giovanni Alfonso Borelli, professor of mathematics at Pisa University. Steno had become the protégé of Vincenzo Viviani, another mathematician of the academy and Borelli's arch enemy. The academy was already split into factions gathering around each of them and it dissolved shortly after.[4] Borelli left Tuscany in 1667 to complete a trilogy on the physical principles of movement.[5] In the third and best known part, *De motu animalium* from 1680/81, he undertook to refute Steno.

What was the scientific substance and background of their conflict? Part of it concerned Borelli's jalousy in relation to a foreign intruder who was thirty years younger than himself and who, within a year of his arrival in Tuscany, received all the attention of the Florentine academy's leaders, including Ferdinand and his brother Leopold (later to become cardinal) and several scholars working in an area of research until then dominated by Borelli.[6] If we take a closer look on their dispute, it does however also reveal incompatible ideas regarding the mechanics of muscle contraction.[7] I have written elsewhere about the conflict between Steno and Borelli, in particular in my introduction to the 1994 edition of Steno's texts entitled *Steno on Muscles*.[8] In the following, I add some points that I have reconsidered since then, while also taking into account the work of later commentators. I will put the conflict with Borelli in the context of Steno's early work on muscles, with particular emphasis on his opposition to Descartes. This allows me to explain in greater detail some difficult technical

3 Steno to Thévenot, [publ. 1667], transl. in SOM, pp. 221–223 (transl. slightly altered). The letter comprises the second part of the *Elementorum myologiæ specimen*.

4 See Boschiero, *Experiment and natural philosophy in seventeenth-century Tuscany*, pp. 37–56 (chapter on Viviani), and pp. 59–92 (chapter on Borelli).

5 See Borelli, *De motu animalium*, 2 vols., 1680–1681, transl. in Borelli, *On the Movement of Animals*; Borelli, *De vi percussionis*, 1667, transl. in Borelli, *Borelli's On the Movement of Animals—On the Force of Percussion*; and G.A. Borelli, *De motionibus naturalibus a gravitate pendentibus*, 1670, transl. in G.A. Borelli, *Borelli's On the Movement of Animals—On the Natural Motions Resulting from Gravity*.

6 See Meli, "The Collaboration between Anatomists and Mathematicians," pp. 665–709.

7 See Kardel, "Function and Structure in Early Modern Biomechanics," pp. 61–70.

8 Kardel, "Stensen's myology in historical perspective," in SOM, pp. 1–57.

aspects of the debate. Next, I consider in some detail the reception of Steno's work on muscle, from the seventeenth century up until today, stressing in particular the importance of a certain Aristotelian axiom in refutations of Steno's "new system of muscle." I conclude the paper with some reflections on Steno's method of scientific reasoning.

2 From the Study of Glands to the Study of Muscle and Brain

Steno was a graduate student in medicine in Amsterdam and Leiden in the Netherlands from 1660 to 1663. He was engaged in the study of the salivary glands and tear ducts when, early 1662, he mentions Descartes for the first time in print, in *De glandulis oculorum*. In this text, Steno stated that his findings on the source of tears disagreed with earlier explanations such as those proposed by "the very clever Descartes."[9]

More on Descartes followed in a letter that Steno sent to Professor Thomas Bartholin, his teacher in Copenhagen, on 26 August, 1662 (it was later published in Bartholin's *Acta medica et philosophica Hafniensia*):

> These days Descartes' *Tractatus de Homine* is released. [...] Figures that are not inelegant and for sure derived from an ingenious brain are presented, but I doubt whether something like that will ever be seen in a brain.[10]

It is followed up on 5 March, 1663:

> Certainly, the more I cut open brains, either of other animals or of various birds, the less the structure of the brain of animals thought out by the noble Descartes, most ingenious and very appropriate otherwise to explain animal actions, seems to fit animals.[11]

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9 KM, p. 412. Steno refers to Descartes, *Les passions de l'âme* (1649), art. 128. See note by Maar in OP I, p. 242.

10 KM, p. 433.

11 OP I, 138, transl. KM, p. 445: "Certe qvo plura tum aliorum animalium, tum varii generis avium aperio cerebra, eo minus animalibus convenire ingeniosissima & actionibus animalibus explicandis admodum alias conveniens cerebri animalium a Nobiliss. Cartesio excogitata fabrica videtur."

On 30 April, 1663, Steno gives the first description of a new structure of muscle. The letter was published by Bartholin in 1667:

> I am busy with a thorough examination of the heart and muscles [...]. As far as their fibres are concerned, I cannot admire their delicate structure enough. Anyone who studies any single fibre will see that in the middle part it is fleshy, and at both extremities it is tendinous, a fact which is well known. But I have more rarely seen described the composition of the junctions. Thus, the fleshy portion does not extend in a straight line from one extremity of the muscle to the other, but it traverses the muscle between the broad [tendon] expansions in such a way that the single fleshy parts run parallel. When making a section from one extremity of the muscle to the other along the direction of the fibres, this structure is clearly seen.[12]

Steno provides two accounts of how this observation was made. The first can be found in his *De musculis* (1664), written a year after it took place:

> But happening to have at hand a dead rabbit, I took hold of a leg and separated its muscles to see whether there was any hope left of attaining any greater certainty. The first which I happened to cut open, after being cut off and divided with one straight section from one extremity to the other, did present itself in the most simple pattern of all that I ever saw afterwards: opposite tendons indeed gathered at the extremities spread out where they had arrived at the fleshy belly so that one expanded through the upper surface of the middle belly and the other through its lower surface and grew more and more slender. The fleshy fibres moved in a straight course between these tendinous expansions, each of them continuing the tendinous fibres. Afterwards I examined many other muscles. All of them without exception fully confirmed my first observation. In all, I found the same pattern as in the first yet not everywhere in the same manner. For in some I observed it quite simple, in others, compound, and this in different ways.[13]

The other description is in a letter to Leibniz from Steno's period as apostolic envoy in Hannover, where he provides an important addition: "The first muscle

12 KM, p. 459.

13 KM, p. 469.

I took from [the leg of a rabbit] showed me the structure of the muscle that until then had not been known to anybody and which completely overturned Mr Descartes' system."[14]

Steno's findings on muscle were incompatible with the loco-motor system of Descartes which had been constructed on ancient concepts. Galen (2nd century AD) records that Erasistratus (3rd Century BC) recognized muscle as a contractile organ that functioned by what seemed to be a simple mechanism of inflation. *Pneuma*, for Erasistratus, was derived from the inhalation of air. The air then travelled from the heart to the brain via the arteries and from the brain to the muscles via the nerves. In Galen's view, Aristotle had said nothing of particular significance with respect to muscle.[15] This ancient assesment was taken up again in the early seventeenth century by Hieronymus Fabricius ab Aquapendente who repeated that Aristotle had "completely ignored" the muscles.[16] And yet, as will be shown later, Aristotle in fact exerted a profound influence on conceptions of muscle contraction in early modern science.[17]

According to Descartes, muscle contraction came about from inflation, caused by animal spirits brought into the muscle from the brain through hollow nerves. Descartes wrote the following regarding motor control from the brain:

> But, to the extant that that spirits thus enter the cavities of the brain, they also leave them and enter the pores of its substance, and from these conduits they proceed to the nerves. And depending on their entering some nerves rather than others, they are able to change the shape of the muscles into which these nerves are inserted and in this way move all [the body's] members.[18]

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14 Steno to Leibniz, November 1677, in Leibniz, *Schriften und Briefe*, II, i, p. 577.

15 Nayler, *A Thorny Problem: Galen, Fabricius and Harvey on Muscle*, p. 26.

16 Fabricius ab Aquapendente, *De Musculis*, in *Opera Omnia* (1687), p. 383 (trans. M. Lærke): "For Aristotle, this most clever student of nature who wrote so precisely, clearly and wisely on animals that he has been equaled by none, completely disregarded the muscles, indeed never even named them, as if the muscles were nowhere in the animal, when in fact there is nowhere in the animal where there is no muscle, and it can be observed how the entire body is covered in, and filled with, muscular flesh."

17 As Peter Distelzweig writes, this was possible because, "for Fabricius, there is no essential tension between the application of mechanics and the employment of Aristotelian resources" (Distelzweig: "Fabricius' Galeno-Aristotelian Teleomechanics of Muscle," p. 82).

18 Descartes, *Treatise of Man*, p. 21 (trans. modified).

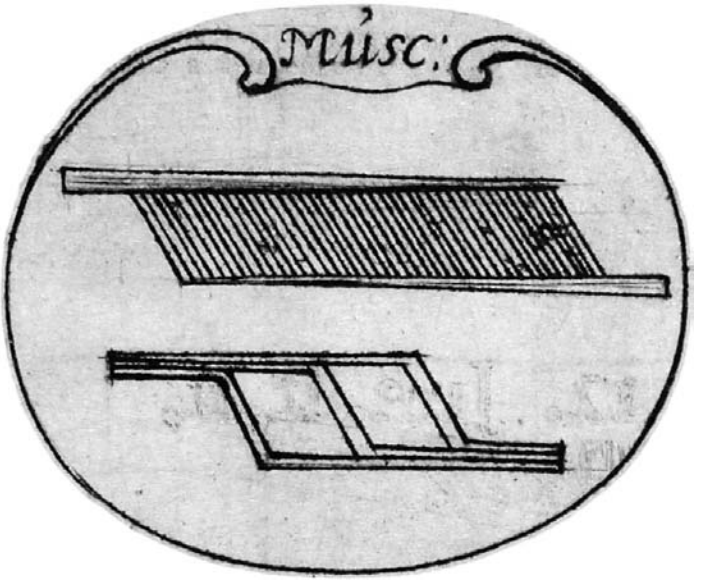

FIGURE 6.1 De Musculis et Glandulis observationum specimen (*Copenhagen 1664*)

Descartes wrote on the action of muscles via nerves:

> Next observe how the [...] little nerve proceeds to the muscle [...] and how it there divides into several branches, [...] so arranged that when the animal spirits enter therein they cause the whole body of muscle to inflate and shorten.[19]

Steno questioned Descartes' functional descriptions that were invented to fit into a hydraulic system. Steno found that several structures described in great detail by Descartes had no anatomical foundation. Thus, within the loco-motor system Steno questioned the brain's motor control by animal spirits. He replaced the notion that the action of muscles was explicable by an inflation brought about by an influx of animal spirits. He suggested instead that it resulted from a shortening of the muscles' fibres in pennate structures.

Steno's research on muscles was first published in Copenhagen 1664 in *De musculis et glandulis observationum specimen*. It included a two-dimensional sketch of a parallelogram of muscle (see Fig. 6.1) and a text describing a three-

19 Ibid., pp. 24–25.

dimensional parallelepiped of muscle. The muscle, according to this model, is thus formed by uniform parallel contractile fibres placed in "rank and order," together forming a parallelepiped of flesh at an angle towards parallel tendons. It is hard to understand the three-dimensional structure just from Steno's words without any corresponding illustration. This is exemplified by a brief excerpt: "From ranks, superimposed on each other so that their middle planes form more or less a parallelepiped, a muscle results where the structure of the ranks is made conspicuous from a series of fibres in the orders, etc."[20] He also described how the contraction of muscle resulted from a shortening of its fibres:

> The action of a muscle is a contraction which does not necessarily result in shortening a straight line between two points at the extremities of the muscle, but always in a shortening of the different fibres of the muscle between these two points.[21]

Steno goes on to note that "the motor fibre rather than the muscle, is what may be termed the animal's organ of movement."[22] So, Steno had described the structural as well as the functional element of his model of muscle contraction before his arrival in Florence.

De musculis was reviewed in the *Journal des Sçavans*. The anonymous reviewer acknowledged that "this will turn upside down what is most basic to medicine." He was not convinced, however, by the description of the shortening of fibres and of the heart as a muscle, thus also stating that "he will never resolve the objections presently made against his project."[23]

From November 1664 to September 1665, Steno resided in Paris, where he was hosted by Melchisédec Thévenot who organized weekly scientific sessions in his home. It was probably during such a session that Steno presented his *Discourse on the Anatomy of the Brain* (published in 1669) which included a critique of Descartes'[24] and Thomas Willis' functional descriptions of the

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20 KM, p. 471. I have later found that Steno's text description of the parallelepiped of muscle in *De Musculis*, 1664 (exemplified above) fits with his illustrations of 1667 (see Fig. 6.2 below).

21 KM, p. 472 (modified).

22 SOM, p. 5. See also Kardel, "Nicolaus Steno's *New Myology* (1667)," p. 37.

23 Anon., on *Nicolai Stenonis De Musculis & Glandulis observationum Specimen*, in *Le Journal des sçavans du Lundy 23. Mars 1665*, p. 139: "Cela va à renverser ce qu'il y a de plus constant de la Medecine," and p. 140: "[…] il ne resoudra point les objections qu'on fait presentement contre son projet."

24 On these issues, see the contribution by R. Andrault in the present volume. Steno's

brain.[25] But it also contained words of praise to Willis for having provided what Steno thought were the best brain illustrations yet. Steno also demonstrated his myology in Paris. Gustav Scherz has drawn attention to the correspondence between the physician André Graindorge and the natural philosopher and Christian apologist, Pierre-Daniel Huet, both from Caen.[26] In his letters from Paris, Graindorge gives a lively picture of the learned circles of Paris. He also praises Steno's skills as an anatomist on several occasions. On 29 July, 1665, Graindorge thus writes the following to Huet regarding Steno's parallelogram of muscle, including also a small drawing:

> I do not remember if I have spoken to you about the mechanics of the muscles: it is something rather curious. Everyone says simply that when the flesh swells up, the muscle shortens. But here is approximately how the machine works: *a* and *b* consist of sinewy bits of matter at the beginning and at the end of the muscle that communicate through the fibres *c c c* in such a way that when these fibres swell up and thus take up more space, the two sinews move towards or away from their extremities as a result of the contraction of the fibres. This is quite curious and easy to observe in each muscle.[27]

Later, Steno moved to Florence to become a scientist at the court of the Grand Duke of Tuscany. Within a year of his arrival, he described a "new system of muscle" in his 1667 *Elementorum myologiæ specimen*, where he described how uniform, parallel contractile fibres crossed the muscle at an angle towards

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critique of Cartesian physiology has also been examined by Auguste Georges-Berthier who concluded that "in Paris, in 1669, Steno made a criticism of the Cartesian hypothesis to which, even today, no important objections can be made. Moreover, Steno denounced, with admirable insight, the arbitrariness of the Cartesian conceptions" (Georges-Berthier, "Le mécanisme Cartésien et la physiologie au XVII[e] siècle," pp. 37–89).

25 Willis, *Cerebri anatome, cui accessit nervorum descriptio et usus* (1664).

26 See Scherz, "Da Stensen var i Paris," pp. 43–52.

27 Graindorge à Huet, 29 July 1665, in Tolmer, "Une page d'histoire des sciences 1661–1669," p. 301: "Je ne sais si je vous ai dit la mécanique des muscles: elle est assez curieuse. Tout le monde se contente de dire que les chairs se gonflant le muscle s'accourcit; mais voici à peu près comme est cette machine: a et b sont les matières tendineuses qui sont à la tête et à la queue du muscle qui se communique par des fibres c c c, en sorte que ses fibres se gonflant et tenant plus d'espace font que les deux tendons s'approches [*sic*] de leur extrémités ou s'éloignent par les [*sic*] rétrécissement des fibres. Cela est assez curieux et bien aisé à voir dans chaque muscle."

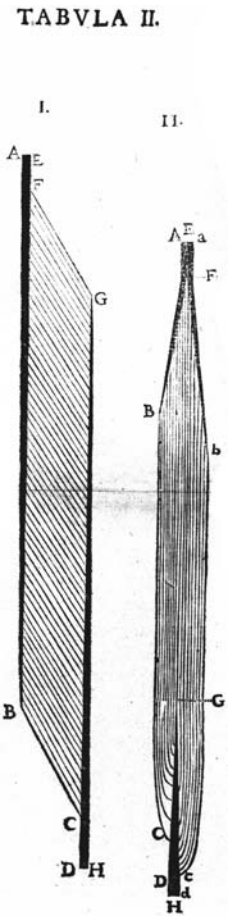

FIGURE 6.2
Part of Tabula II in N. Stenonis, Elementorum Myologiæ Specimen (*Florence 1667*)

parallel tendons. This new system was intended to replace the "ancient system of muscle" with fibres going from one end of the muscle to the other.

Figure 6.2 shows Steno's unipennate structure of human muscle in a woodblock print. The figure depicts the inner structure of a human skeletal muscle in two dimensions, more precisely the unipennate gastrocnemius muscle cut in a frontal plane that displays the muscle's "thickness." Panel I represents the unipennate *gastrocnemius* muscle in a frontal plane. Panel II represents the bipennate *biceps brachii* muscle in a sagittal plane.[28] Both panels show Steno's

28 Stensen's description of the structure of skeletal muscle in several muscles has been confirmed in postmortem examinations of humans and, more recently, in examinations

"plane of the order" (*ordo*), where the "thickness" (*crassitudo*) of the muscle increases in contraction. The "width," Steno's "plane of the rank" (*verso*), which is perpendicular to the plane of the drawing, remains unchanged in contraction. According to the geometrical model of contraction, albeit Steno does not note this, the *biceps brachii* muscle mostly swells in an anterior direction and the *gastrocnemius* muscle swells to the sides.

Steno also gave a schematic representation of the internal morphology of unipennate muscle (see figure 6.3 below). Panel II shows a single muscle fibre with slight angulation between the contractile middle part and the tendons. Panel III shows a (hypothetical) sample of staggered muscle fibres without angulation towards the tendinous parts. Panels IV and V show cross-sections through pennate muscle in the plane of the order which displays the parallelogram of muscle. Panel VI shows muscle fibres in the plane of ranks perpendicular to the plane of order. Finally, in panel VII, the muscle fibres in order and rank are combined as the parallelepiped of muscle. Note that the two lower diagrams are drawn in true perspective.

According to Steno, the swelling of contracting muscles is caused by the fact that they shorten. This is the exact contrary of the ancient conception according to which the shortening of a contracting muscle is caused by swelling. According to some authors, then, and notably Descartes as already mentioned,[29] this swelling involved an expansion of volume caused by material brought into the muscle via the nerve. Others, such as the authors from the Royal Society in London, held that the swelling was caused by a chemical process within the muscle itself.

Steno stood alone with his "new myology". As he noted himself: "I can imagine that a number of people will stop and decide that this new muscle structure is just another chimera."[30] This is a very strong statement to put in a

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in vivo by means of composite ultrasound imaging, for example in the case of the *biceps brachii* muscle. From the illustration in Pappas et al., it is possible to identify the sagittal plane of the *biceps* muscle depicted by Steno (see Pappas et al., "Nonuniform shortening in the biceps brachii during elbow flexion", pp. 2381–2389, esp. fig. 1). It is also possible for the gastrocnemius muscle (see Martin et al., "Comparing human skeletal muscle architectural parameters of cadavers with in vivo ultrasonographic measurements," pp. 429–434, esp. fig. 3 and 4).

29 Descartes, *Treatise of Man*, p. 17.

30 SOM, pp. 94–95: "*Videor mihi videre multos, qui ad prima hæc verba pedem figentes, novam musculi fabricam, novam chimæra pronuntiaturi sunt.*"

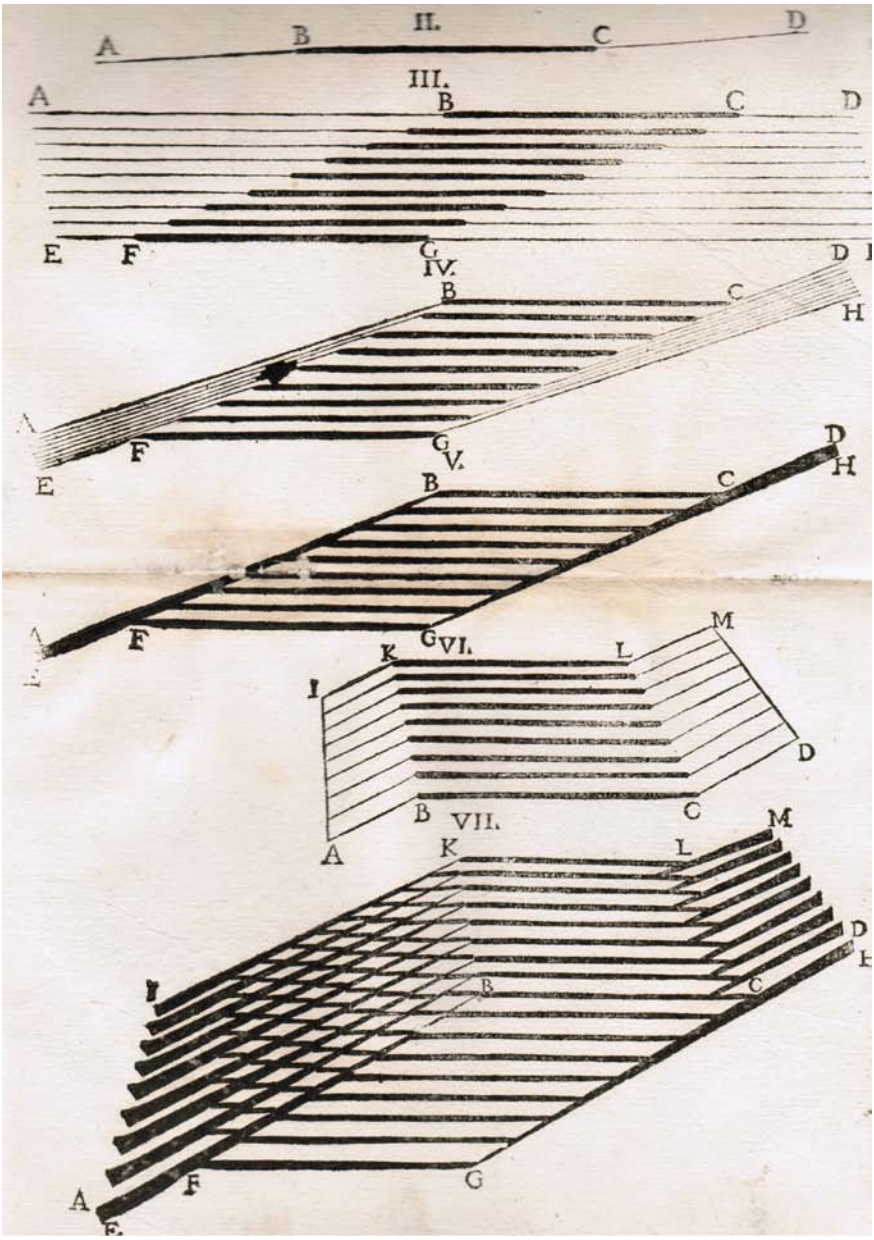

FIGURE 6.3 *N. Stenonis,* Elementorum Myologiae Specimen*, Florence 1667*

scientific report and suggests that his myology had received harsh comments. Steno's appeal to fibre shortening as the functional element in his myology was most likely the principal cause of criticism. Certainly, I have not come upon

any contemporary commentary that explicitly calls his myology a 'chimera'.[31] I can, however, draw attention to a discussion of muscle contraction reported by the *Acta Eruditorum* in September 1721, where Leibniz is quoted for considering attracting forces to be chimeras. In this account, which includes no less than ten lengthy comments on muscle contraction, the anonymous author does not even touch upon the subject of fibre shortening. Steno is mentioned only in connection with the so-called 'Steno-experiment' in which he demonstrated how a reversible paralysis occured during the temporary ligature of the abdominal aorta of a dog.[32] In many ways, the whole erudite discussion about myology at the time simply ignored Steno's central thesis. Steno, for his part, did not take this harsh reception too seriously, but continued to think highly of his own work: "I have often desired to undertake this work. But I would never pretend that what pleases me should be accepted by all others. According to an old saying, love makes people blind to their own progeny, and it is a frequent experience that what displeases other people is often what pleases authors most."[33]

3 Steno's Geometrical Argumentation in Four Steps

The geometrical model of the muscles in the *Elementorum myologiae specimen* (1667) is developed in four steps: definitions of the structure of the muscle; suppositions on the movement of the structure; lemmas that demonstrate the shape of the model in motion; and the main proposition.

1. Forty-four definitions based on anatomical investigation define the outer and inner structure of skeletal muscle as a parallelepiped of flesh filled with parallel uniform fibres.[34] The single motor fibres of the flesh are then defined and drawn as long, thin parallelepipeds. The latter definition is hypothetical and in reality wrong.[35] But since the shape of single muscle fibre is not used in the geometrical deduction, it does not interfere with the conclusion.

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31 See Anon., *Virii Cel. Joannis Bernoulli, Matheseos Professoris Basilensis ac Scient. Acad. Reg. Quæ Parisiis, Londini & Berolini sunt, Socii, de Motu musculorum, de effervscentia & fermentatione Dissertationes Physico-Mechanicæ* (1721), p. 393 and 395, transl. in Kardel, "Prelude to Two Dissertations by Johann Bernoulli," p. 30.

32 KM, p. 582.

33 SOM, pp. 92–93.

34 SOM, pp. 96–119. Note in particular the drawing of a single motor fibre, p. 102.

35 I have noted this error in SOM, p. 19.

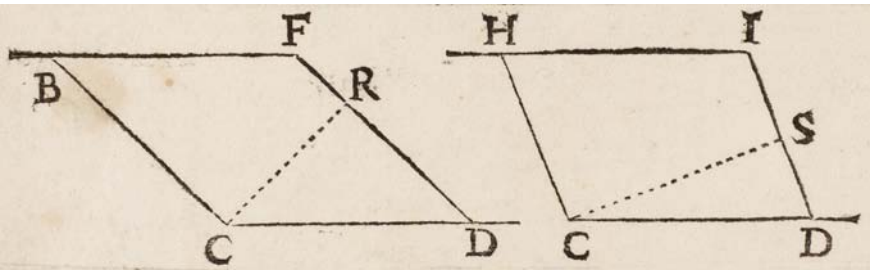

FIGURE 6.4 *N. Stenonis,* Elementorum Myologiæ Specimen (*Florence 1667*)

2. Five suppositions stating that when the muscle contracts the individual parts all along the flesh shorten equally.[36]
3. Six lemmas stating that the parallelepiped structure is maintained during the contraction of the fibres.[37]
4. One main proposition: "Every muscle swells when contracting."[38]

Even if the volume of the muscle remains constant on Steno's model, the contracting muscle will swell. He provides easy to understand illustrations of this by means of parallelograms in a two-dimensional geometry. Consider Figure 6.4. In the left figure, BC and its parallels illustrate muscle fibres in relaxation. In the right figure, HC and its parallels illustrate fibres in contraction. Parallelograms having the same base and in the same parallels are equal according to Euclid (Prop. I.35),[39] but the thickness CS is greater in contraction than CR in relaxation. Muscle fibre BC shortens to become HC in contraction giving a shorter muscle since BD>HD. There is no change of area but an increased thickness of muscle, since CS>CR. Next, Steno describes in a three-dimensional way how the parallelepiped of the flesh in reality involves a thickness [*crassitudo*], CS, and a width [*latitudo*], DK, as shown in Fig. 6.5.[40]

Figure 6.5 is a superimposed three-dimensional illustration of Steno's two-phase model of contraction of unipennate muscle displayed in relaxation (delimited by C D K M—F I H B) and in contraction (delimited by C D K M—P Q O M). Homogeneous passive muscle fibres, such as B C and those parallel to it, and actively shortened muscle fibres such as C N and parallel ones, enable a

36 SOM, pp. 122–123.

37 SOM, pp. 124–139.

38 SOM, 138–139.

39 SOM, p. 243. Steno's references to Euclid are cited according to Euclid, *The Thirteen Books of The Elements*.

40 SOM, p. 118.

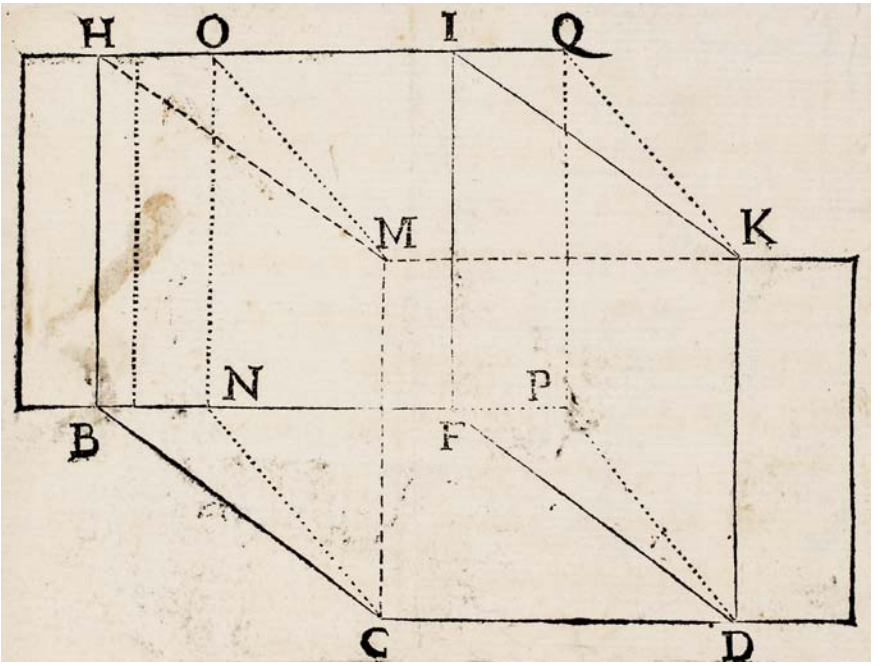

FIGURE 6.5 *Sketch from N. Stenonis,* Elementorum Myologiæ Specimen (*Florence 1667*)

shortening of the whole muscle (i.e. the distance B D > N D). According to Euclid (XI.29) this happens without any change of volume of the parallelepiped. As in the simpler two-dimensional projection (Fig. 6.4, above), an impression of swelling of the muscle may be created because the projection of C on its opposite tendon-face in the passive muscle D F (not drawn) is smaller than its projection on D P (also not drawn) after active shortening. On active shortening one tendon plate (C M K D) is fixed. On shortening the opposite tendon plate can move (B F H I to N O Q P) like a swaying tower over the fixed base. The muscle fibres are at an angle, the pennation angle, towards the tendons CMKD and BHIF.

The "Proposition" states that the thickness of muscles increases when they contract: "Every muscle swells when contracting. Since the swelling [*tumor*] is nothing but an increase in one or more dimensions, an increase of a muscle's thickness is the same as the occurrence of swelling in that muscle."[41] Similarly, he observes regarding width in supposition 4: "When the flesh shortens, its

41 SOM, p. 139 (translation altered).

width remains the same."[42] However, according to Euclid, "parallelepipedal solids which are on the same base and of the same height, and in which the extremities of the sides which stand up are on the same straight lines, are equal to one another" (Prop. XI.29). Therefore, the volume of the parallelepiped of the flesh remains the same, regardless of whether the muscle is contracted or relaxed. Steno had thus demonstrated that, in every muscle with pennate structure, a swelling could occur even if no new substance entered the muscle, namely when contraction results from a shortening of the fibres, because the volume of the model is the same in relaxation and contraction.

Steno used the notion of fibre shortening to argue that muscle volume remains the same in contraction. Both these points, fibre shortening and unchanged volume during contraction, did however remain experimentally unconfirmed. Steno argued as if he was trying to solve an equation with two unknown variables. Certainly, even if this cannot be done, it does not mean that the quantities of the equation are wrong, but Steno's myology became easy prey for opponents, because it lacked published evidence of one of the premises as well as of the conclusion.

Steno did not imply that he had proven that the volume of muscles remains unchanged in contraction. He only proved the usefulness of the new myology in the face of the objections that had been leveled against him:

> This is what I had promised to demonstrate, in part to make it clear that, whatever clever arguments are proposed from several sides about an influx of new substance into the muscle, they are by no means proven, and in part to show the usefulness of the new muscle structure to explain the movement of muscles, (and) the structure *they* (Steno's opponents) propose is unlikely to be any natural structure.[43]

Steno refrained from resorting to animal spirits to describe muscular action and he admitted his ignorance when it came to the cause of fibre-shortening. This was perhaps the target of a remark by Borelli in his *On the Movement of Animals*: "The position of those who admit their ignorance of the causes of natural matters has always appeared to me as more commendable than those who take the liberty of being daring in Philosophy."[44] Steno also acknolwedged that a model of muscle contraction including only two elements was reductive: "[…]

42 SOM, p. 123.

43 SOM, p. 149.

44 Borelli, *On the Movement of Animals*, II, Prop. XXVIII, p. 237.

as I am not going to propose all the elements of myology, but only to provide those which are sufficient for a clear understanding of the muscle structure."[45] It is, however, worth noting in this context that the earliest computer models of muscular contraction were also built on only two elements, muscle structure and fibre characteristics (see also below in section 6).

Steno did not use the model of muscle contraction for calculations. The later models of Borelli and Bernoulli failed, as their calculations were based on erroneous assumptions.[46]

4 Contemporary Authors

The *Elementorum myologiæ specimen* was published in a period with several active researchers in the field and prompted a variety of reactions. The first was a careful review published in London on February 10, 1668.[47] After that, a long list of natural scientists commented on Steno's work.

1. I would be remiss in discussing this area of research without mentioning Jan Swammerdam, the great Dutch anatomist and entomologist who was a friend and companion of Steno during studies in Leiden and Paris. In Leiden, Swammerdam had carried out experiments showing that muscles do not increase their volume when contracting. Steno probably knew about these experiments.[48] Swammerdam placed frog gastrocnemius or heart muscle in glass syringes with a narrow open tip blocked by a colored droplet to indicate

45 SOM, p. 120: "Quod hic factum, cum non mihi animus sit ipsa elementa myologiæ proponere, sed duntaxat tale illorum specimen edere, quod sufficeret fabricæ musculi distinctè intelligendæ." The title *Elementorum myologiæ Specimen* may allude to these two "elements" among other "specimens" mentioned.

46 See his *Principles of Animal Mechanics* (1873), pp. 73–74, the Rev. Samuel Haughton recalculated forces from Borelli's experiments and identified several "errors of observation" and "mechanical blunders". Bernoulli applied differential calculus on the expansion of imagined microstructures to calculate the amount of animal spirit spent when a muscle lifts different weights, see Kardel, "Prelude," p. 32. See also Nayler, *The Insoluble Problem*, p. 538.

47 Nayler writes on the review in London: "This is one of the few correct statements concerning Steno's work, as the majority of contemporary accounts, often outlining his proposed muscle structure with varying degrees of clarity and verisimilitude, add a cause of contraction where Steno was content to leave aside [the causal question]" (op. cit., pp. 274–276).

48 Steno refers to the experiments of his "friend Swammerdam" in OP II, p. 101.

volume changes of muscle within the restricted space. Then he induced contraction and did not find any increase in volume.[49] This crucial evidence for Steno's myology was not followed up and remained unpublished until 1737.[50]

2. Another experiment that likewise indicated that the action of muscles did not involve noticeable volume change was conducted by Jonathan Goddard and reported to the Royal Society of London on 16 December, 1669. It was mentioned in the society's minutes but remained unpublished until 1756. Goddard placed the arm of a subject in a tight "plethysmograph" that enabled observation of changes in volume all the way down to arterial pulsations. No consistent volume changes took place during the movement of the hand.[51]

3. The ancient theory of contraction by inflation did however also find some new support, for example in the *Experiment Concerning the Force of Blowing with a Man's Breath* conducted by John Wilkins on 31 July and 4 September, 1661.[52] Wilkins' experiment was often quoted in support of contraction by inflation and also discussed by William Croone on 6 November 1661: *An Experimentall Account of the Raising up of a Weight Hung at the Bottom of an emptie Bladder*.[53]

4. An early example of the use of geometrical reasoning when accounting for muscle contraction can be found in Walter Charleton's 1658 *On the Reason of the Movement of Muscles*.

> It seems more reasonable, that this swelling in the body of the muscle is the cause of its contraction; than, on the contrary, that the contraction

49 See Swammerdam, "Versuche, die besondere Bewegung der Fleischstränge am Frosche betreffend, […] aus Bibel der Natur," pp. 83–135.

50 SOM, pp. 16–17.

51 Ibid., p. 27. Birch, *The History of the Royal Society of London*, vol. 2, pp. 411–412.

52 Ibid., vol. 1, p. 36. Johann Bernoulli (1694) compared his own infinitesimal calculations of inflation of muscles with traditional calculations made by John Wallis based on Wilkins' experiment on the bladder of a cow. Bernoulli reflected, "this experiment not only is explained more easily by what we wrote but also can be more accurately calculated by our theory than Wallis did" (Bernoulli, *Dissertations on the Mechanics of the movement of Muscles*, § 14 in p. 17 and pp. 129–131).

53 Birch, *The History of the Royal Society*, vol. 1, p. 53. See Nayler, "Introduction" in W. Croone, *On the Reason of the Movement of Muscles*, p. 9.

> should be the cause of the swelling, as those contend who would have the motion to be performed without the afflux of spirits.[54]

In Charleton's sketch, the muscles of the human arm shorten like a rectangle becoming shorter and wider. A rectangle is the two-dimensional equivalent to the shortening cylinder. Charleton's illustration was directly copied from a dissertation by Jacob Müller[55] according to which, when muscles contract, they "gain as much in depth and width as they lose in length and hold prominent the whole bulk of their body." It is not clear whether Steno commented on Müller or on Charleton, but he (correctly) noted that "an explanation with rectangles does not agree with nature."[56]

5. In 1664, William Croone gave a more detailed geometrical representation of muscle contraction. According to him, when a muscle swells it produces a pull on the tendon.[57] Steno and Croone met in Montpellier in 1666 just two years after having, independently, published their conflicting accounts of muscle contraction.[58] As Leonard G. Wilson has noted, Croone must have felt rather crushed by Steno's arguments.[59] Nevertheless, as Nayler writes, "although Steno's *Elementorum myologiae Specimen* (1667) offered a geometrical proof that a contracting muscle could swell without the influx of new material, this and other arguments adduced by Steno seem to have had no impact on Croone's thinking."[60] Croone remained in favor of the traditional view of action from inflation. He was later comforted in this opinion by "that long expected work" that was Borelli's 1680 presentation of his inflationist ideas.

6. In 1677, the Dutch pioneer in microscopy Anton van Leeuwenhoek sent a letter on the microstructure of muscle to the Royal Society of London, including some sketches of "globules."[61] A globular structure of muscle agreed with

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54 Nayler, *A Thorny Problem*, p. 227, quoting W. Charleton, *Natural History of Nutrition, Life and Motion* (1659), p. 188. See also Booth, *A Subtle and Mysterious Machine*.

55 Müller, *De natura motus animalis et voluntarii* (1617). On Müller, see also Van de Linden, *Lindenius renovatus, sive, Johannis Antonidae van der Linden, De scriptis Medicis Libri duo* (1686), p. 489.

56 SOM, p. 123.

57 SOM, pp. 8–9. See also Nayler, "Introduction," pp. 2–53.

58 SOM, pp. 25–27.

59 Wilson, "William Croone's theory of muscular contraction," pp. 158–178.

60 Croone, *On the Reason of the Movement of Muscles*, pp. 37–38.

61 See Van Leeuwenhoek, "Mr Leewenhoecks Letter Written to the Publisher from Delft the

Croone's inflation theory as he reported in 1674 and 1675 in the Surgeon's Theatre in London.[62]

7. Several other members of the Royal Society reported on Steno's research on muscle contraction. Thomas Willis quoted Steno eight times in his work of myology. It was, incidentally, the only author he quoted. Willis endorsed the ancient theory of effervescence within the muscle as the cause of its contraction. Willis illustrated this with a drawing of muscle having a typical pennate structure.[63]

8. Richard Lower, earlier an assistant to Willis, made drawings depicting the fibres of the skeletal muscles and the heart, crediting Steno for the design. Lower rejected inflation and the ancient structure.[64] Lower's description, however, received little attention at the time.

9. In his 1674 *Tractatus quinque medico-physici*, John Mayow agreed with Willis on muscular action by inflation.[65] In order to account for an expansion of the muscle brought about by what he called nitro-aerial particles, Mayow corrupted Steno's parallelogram model by increasing the distance between the parallel tendons during action. He thus made room for new matter to be brought into the muscle through the channel of the nerves which, according to Mayow, was required in order for contraction to begin: "While the muscle is changed as to shape, it swells as to breadth, but becomes less as to length; and in this way a muscle can be shortened, although its fibres suffer no contraction."[66] Mayow's parallelogram (Fig. 6.6) resembles that of Steno and was sometimes mistaken for being identical to it, for example in the work of Herman Boerhaave and Albrecht von Haller.[67]

14th of May 1677, Concerning the Observations by him Made of the Carneous Fibres of a Muscle, and the Cortical and Medullar Part of the Brain" (1677–1678), p. 900: "I have used several methods of observing, to see the particles of these Carneous filaments, […] to which I can give no other figure than globular." Such "globules" may have been cross sections of muscle.

62 SOM, pp. 26–27.

63 Kardel, "Willis and Steno on Muscles," pp. 100–107.

64 SOM, pp. 28–29.

65 See Mayow, *Tractatus quinque medico-physici* (1674), part IV: "De motu musculari et spiritibus animalibus."

66 See SOM, pp. 32–33.

67 See SOM, pp. 40–41.

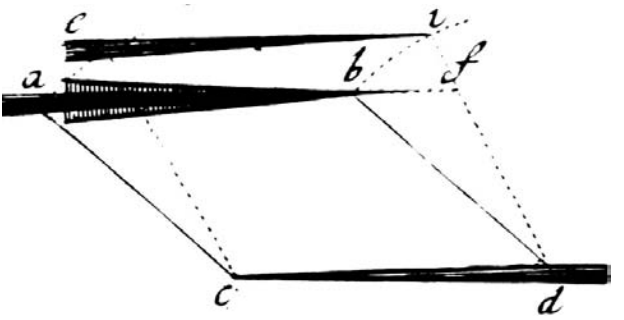

FIGURE 6.6 *Mayow's mistaken parallelogram without shortening of the muscle fibres. Plate III, fig. 1 from J. Mayow,* Tractatus quinque (*London, 1674*).

Despite the resemblance with Steno's figures, in Mayow's figure the fibres in relaxation *ca* and *db* are equal to the fibres in contraction *ce* and *di*.[68] Thus the area of Mayow's parallelogram increases in contraction to allow space for volume expansion.

10. In the Cimento Academy, Vincenzo Viviani, mathematician and a pupil of Galileo, helped Steno, but he never published or commented on muscle in written reports or in their correspondence. How much Viviani understood on the topic remains unclear. The help Steno received from Viviani to express his myology in geometrical terms and figures has been stressed by Domenico B. Meli.[69]

Except for Lower, nobody took up Steno's ideas on muscle in a constructive way. In the Netherlands, Steno's respected anatomy teachers, Franciscus Sylvius and Johannes van Horne, soon died in old age. The use of mathematics in the account of muscle contraction soon became an obstacle rather than an aid, because muscles cannot be treated mathematically in a meaningful way unless fibre shortening as proposed by Steno is accepted. And no one did that, and least of all Borelli.

11. When Steno brought mathematics into the study of animal movement, he had entered the scientific field of Giovanni Alfonso Borelli, the inflationist

68 If this be true, the outlet through which the expansion material is removed in relaxation remains an unaddressed problem.

69 See Meli, "The Collaboration Between Anatomists and Mathematicians," pp. 693–706. Meli mentions how unusual and original the myology was. See also Boschiero, *Experiment and natural philosophy*, pp. 59–92.

par excellence. Borelli fought back even from his deathbed in Rome, when publishing *De motu animalium*.[70] In this work, he announces from the outset a sharp response to the new thoughts on the so-called true shape of muscle by "some authors". Without mentioning Steno by name, Borelli denounced "all this reasoning solely based on the trite Euclidean proposition: two parallelograms formed by two lines with the same base are equal."[71] In a sense, I agree: the geometry in the *Elementorum myologiæ specimen* is at a basic level, "trite" as Borelli holds. But what makes Steno's model unique is not the geometry. As I see it, his geometrical figures are observation-based workable estimates of skeletal muscle, a point missed by most commentators.

According to Borelli, "muscles do not contract by condensing the length of their fibres, but their hardness and tightening result from swelling," for "there is no attraction in nature and almost everybody finds such attraction ridiculous now."[72] According to Borelli, swelling results from a chemical process in so-called rhomboidal machines in continuous series like a chain. The same applies to the heart: "The fibres are not aimed by nature at pulling and bringing their extremities closer together. In contracting the fibres swell and decrease the cavity [of the heart]. In so doing they squeeze out the blood contained in it, like a press."[73]

Besides providing an illustrated mechanical description of human and animal walking, lifting, and swimming, etc., *De motu animalium* attempts to describe and defend contraction by inflation and to refute "those" who deny that. Steno had now become bishop in Münster in Westphalia. He gave no response we know of, perhaps because Borelli had published his work with a dedication to, and the support of, Christina, the converted and exiled queen of Sweden with tight connections to the Holy See.

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70 On Borelli's death, see Giovanni, "Benevolent Reader, greetings," in Borelli, *On the Movement of Animals*, pp. 3–5. Borelli kept opponents anonymous: "Whenever I criticize opinions, I do not attack the names of the authors or their fame" (Borelli, *On the Natural Motions Resulting from Gravity*, "Foreword to the Reader," p. v). Steno also kept his adversary anonymous. This was possibly a code of conduct in the Cimento Academy.

71 Borelli, *On the Movement of Animals*, Chap. II, prop. 5, p. 12: "Et hæc tota speculatio nititur tritæ illi propositioni Euclidis, quod duo prismata super eadem basi inter duo plana Parallela constituta sint inter se æqualia & è converso." More recently, Kirsti Andersen, a historian of mathematics, has also remarked that even though Steno's "result is not very satisfactory, his approach attracted some attention, and Johann Bernoulli referred to it" (Andersen, "An Impression of Mathematics in Denmark in the Period 1600–1800," p. 319).

72 Borelli, *On the Movement of Animals*, chap. I, prop. 14, p. 217; and chap. II. prop. 139, p. 346.

73 Ibid., chap. I, prop. 38, p. 250.

5 The Aristotelian Physical Axiom and the Refutation of Steno

Borelli's views were reintroduced and partly renewed by the Swiss mathematician Johann Bernoulli. Borelli's *De motu animalium* was republished with Bernoulli's commentary in 1710, 1734 and 1743. In Bernoulli's (second) academic dissertation of 1694 entitled *De motu musculorum*, he followed in the footsteps of Borelli, Mayow and Willis:

> The theory of Stensen on which Borelli and Mayow should be consulted is refuted by many other arguments. As I suspect, those who deduced that muscular contraction results from some swelling discovered the actual cause of contraction of the muscles. Among them the most important are Willis and the two authors mentioned above. All of them agree that ebullition begins in muscles, distending the fibres so that they lose in length what they gain in width.[74]

Bernoulli flatly denied Steno's description of muscular contraction without the influx of new material as *ridicula*. We can best understand how Bernoulli used Borelli to refute Steno by taking our point of departure in his definition of animal spirits:

> We therefore state with Borelli that the nerves are collections of tubes full of some spongy substance. This substance is always turgid, full of a very spirituous juice provided by the brain and of a nature such that when mixed with blood it boils instantaneously. This juice is commonly called animal spirits. If the soul commands or exerts an act of will, this can occur only through the necessity of a wonderful union which God Almighty constituted between our soul and body and which so far remains hidden and will remain so.[75]

Bernoulli mentions how to calculate the amount of animal spirit needed to lift a load using the differential calculus, basing his calculations on anatomical inventions described by Borelli and, via Borelli, by Croone:

> In this matter we will follow the tracks of the incomparable gentleman Giovanni Alfonso Borelli by adopting his hypothesis. We shall, however,

74 Bernoulli, *On the Movement of Muscles*, § 3, pp. 108–109.

75 Ibid., § 4, p. 109.

> show that he applied this hypothesis too carelessly when he assigned a rhomboid shape to his small machines or vesicles of the muscular fibres. It will also appear that he attributed this shape for the sake of facility so as to compute by an easier calculation the relations of the dilating forces to the resistances, and also because he could not know the right and due shape (which we shall demonstrate must be circular because of the nature of the pressures of liquids).[76]

Bernoulli refrained from making new anatomical studies, arguing that "this has assuredly been done more than enough by the most prestigious anatomists who have excelled in this century and do excel still now."[77] Consequently, Bernoulli's objections against Steno's myology were based on philosophical assumptions, not observation:

> In his *Specimen of Myology*, Steno believes that muscle contracts without any arrival of new substance, only by modifying its shape, changing from an oblique parallelogram to a less oblique. This opinion is altogether ridiculous and must be considered as pure game of the mind of its author. Indeed, apart from the fact that contraction of a rectangular muscle cannot be explained in this manner without penetration of a body, this theory does not explain what moves a muscle, what its prime mover is or how this common axiom of physics can be applied: *Everything that is in motion must be moved by something*.[78]

As both Raphaële Andrault and myself have pointed out, Bernoulli's reason for not accepting fibre shortening was philosophical. It related to the Aristotelian axiom italized in the quote, originating from book VII of Physics: "Everything that is in motion must be moved by something."[79] This axiom was already highlighted in the early 17th century in *De motu locali animalium* by Fabricius ab Aquapendente, in an Aristotelian discussion of the principles of muscular motion.[80] When denying self-motion Borelli appealed to its consequence: "We

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76 Ibid., "Foreword," pp. 102–103.

77 Ibid.

78 Ibid., § 3, pp. 108–109: "[…] vel qua ratione tritum illud axioma Physicum salvetur: *Omne qua movetur, movetur ab alio*." Bernoulli cites Aristotle, *Physics*, Bk, VII. For a translation, see Aristotle, *The Complete Works of Aristotle*, vol. I, p. 407.

79 Kardel in SOM, p. 40, and in "Prelude to two dissertations by Johann Bernoulli," pp. 32–33. See also Andrault, "Mathématiser l'anatomie: la myologie de Stensen (1667)," p. 529.

80 Fabricius ab Aquapendente, *De motu locali animalium* [orig. 1618], in *Opera Omnia* (1738),

have shown that there is no attraction in nature and that, nowadays, almost everyone finds such attraction ridiculous."[81] As Michael F. Frampton explains, because of this axiom, Aristotelian physics requires pushing or pulling in order for movement to occur. As he writes: "Now the outputs of movement are pushing and pulling. Accordingly, the instrument of movement must be capable of expanding and contracting; and this is precisely the nature of breath (Aristotle, *Motion of animals*)."[82] Fibre shortening as Steno saw it seemed like a kind of self-movement. Consequently, it seemed to be ruled out by this Aristotelian tradition, which, via Fabricius ab Aquapendente, had been transmitted to other authors writing on muscle contraction in the seventeenth century.[83] The axiom finally acquired its full significance in Bernoulli because he was explicitly adhering to the kind of corpuscular mechanics that considered all causes of movement to be solely mechanical while also subscribing to the Aristotelian denial of the vacuum. This implied that bodies could only move because of other bodies and through contact.[84]

Johann Bernoulli published a short report of his myology in the influential *Acta Eruditorum*.[85] As a result of this, the theory developed by Borelli, based on Croone, according to which muscular action results from the distension of hollow machines gained impact and credibility from refined new mathematical analysis. But an otherwise correct mathematical analysis will not help if it is based on faulty premises.

6 Later Assessments

Daniel Bernoulli, Johann's son, kept to the family trade, mathematics. When he became professor in St. Petersburg, he gave an inaugural lecture, published

p. 332: "Ad primum quod attinet, demonstratum est ex Aristot. *in omni motu requiri movens, & mobile, hoc est, id quod movetur*." In his text, Fabricius refers to Aristotle in Q.3 and Q.29. See also Kardel, "Nicolaus Steno's New Myology," p. 63.

81 Borelli, *On the Movement of Animals*, II, prop. CXXXIX, p. 346 (translation altered).

82 Frampton, "Aristotle's Cardiocentric Model of Animal Locomotion," p. 312.

83 See Stannard, "Aristotelian influences and references in Harvey's *De motu animalium*," pp. 122–131.

84 These same corpuscularian notions were to plague Newton's theory regarding the force of gravity. See Popper, *Conjectures and Refutations*, p. 93.

85 See Bernoulli, "De Motu Musculorum Meditationes Mathematicae, communicatae a Joh. Bernoullio Basil. Med. Doctore" (1694), pp. 200–206.

under the title *Tentamen novae de Motu Musculorum Theoriae* in 1726.[86] In it, he affirmed, as had his father before him, that "most physiologists state that inflation of muscles cannot occur without previous influx of animal spirits through the nerves into the muscle fibres."[87] He also studied mathematically a segmented fibre model in which the cylindrical segments turned barrel-like from inflation when in action.

The British anatomist and surgeon James Douglas, the Croonian lecturer before the Royal Society in 1741, published his *Myographia* in 1707. It was popular and frequently re-edited until 1760. Douglas subscribed to Bernoulli's account of muscular motion. Indeed, according to Douglas, it "seem[ed] to be the most natural and the most agreeable to the rules of mechanism of any that has hitherto been advanced."[88]

In a review in the *Journal des Sçavans* of the *Elementorum Myologiae Specimen*, re-published in Amsterdam 1711, the reviewer notices that

> in this myology, which is sufficiently known by the public, and of which we speak of only because a new edition is given us, the purpose of Mr Steno explains the mechanics of the function of the muscles according to the principles of geometry and claims that the contraction of the muscles must not be attributed to the involvement or the rarefaction of the animal spirits [...]. These explanations cannot be understood without the help of several figures drawn on paper. Moreover, they require attention, not to say a very particular meditation. We believe it is more convenient to refer the readers to the book of Mr Steno than to risk to bore them with a summary which may only increase the obscurity of the matter already obscure by itself.[89]

Moreover, the reviewer finds little of general interest in the two added shark dissections, arguing that "neither of them contains anything which might excite the curiosity of those who are not versed in the science of anatomy." The review confirms that Steno's observation-based hypotheses about the muscles and about geology were far from acknowledged laf a century after their publication.

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86 Bernoulli, *Tentamen novae de motu musculorum theoriae* (1726), in *Die Werke von Daniel Bernoulli*, vol. 1, pp. 92–103.

87 Kardel, "Prelude to two dissertations," p. 25.

88 Douglas, *Myographiae comparatae specimen, or, a comparative description of all the muscles in a man and in a quadruped* (1707), p. xix.

89 Anon., "Elementorum Myologiae Specimen," *Journal des Sçavans* (1711), pp. 523–525, transl. P. Maquet.

In his lecture no. 415 in Leiden, published posthumously in 1743, Hermann Boerhaave described a parallelogram model of muscle allegedly by Steno, noting that

> this most brilliant man [...] had not paid attention to another theorem from mathematics from which we teach that among parallelograms the rectangle includes the greatest area, when any figure of them have equal interchangeable lines. Therefore the greater space is contained within the same perimeter.[90]

Unfortunately, however, Boerhaave commented on Mayow's model, not Steno's. Steno's myology was also rejected curtly by the great compiler of physiology, Albrecht von Haller, a student of Johann Bernoulli and Boerhaave, in his authoritative *Elementa physiologiae corporis humani* from 1762. Haller mistook Mayow's parallelogram for Steno's and concluded: "This structure is not true. It is rare to be offered muscles of this kind [...]."[91]

Margaret Nayler has noted how James Parsons, in the Croonian Lecture in 1744–1745, disgracefully relegated Steno to a remote corner of the historical background. Indeed, as Nayler commented, "as to Steno's proposed muscle structure, Parsons believes that 'none but the Author himself ever fancied he saw them so'," and Nayler holds that "Parsons' sketch illustrating what happens on contraction is both misleading and inaccurate."[92]

In the posthumous edition from 1761 of the anatomical works by Joseph-Guichard Duverney, professor in Paris, the Aristotelean physical axiom was, for the last time it seems, used against Steno's myology.[93]

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90 Ch. 6.2, "Hermann Boerhaave," in SOM, pp. 40–41.

91 Ch. 6.3, "Albrecht von Haller: 1762," in SOM, p. 41.

92 Nayler, *The Insoluble Problem*, p. 285 and 285a. Nayler cites Parsons, "Steno," in *The Crounian Lecture on Muscular Motion* (1756), p. 1119. Parsons refers to Steno's *De Musculis*.

93 See Duverney, *Traité de Myologie*, in *Oeuvres anatomiques* (1761), vol. I, p. 491: "Steno attributes the shortening of muscles solely to a change in the angle of the fibres, without any addition of any new matter. This hypothesis is incompatible with the law of nature according to which a body in rest can receive no change from itself and will always remain without movement if it does not receive a change from something exterior to it which makes it move [*Stenon attribue le raccourcissement des muscles au seul changement de figure des angles des fibres, sans le secours d'aucune nouvelle matière. Cette hypothèse est incompatible avec une loi de la nature, sçavoir qu'un corps qui est en repos, ne peut recevoir du changement par lui-même, & qu'il sera toujours privé de mouvement, s'il ne reçoit du changement par quelque chose qui soit hors de lui, qui le mette en mouvement.*]"

C.C.A. Gosch, the Danish zoologist and diplomat, compiled Danish biological research in 1873. Gosch concluded that Borelli, Mayow, Bernoulli and Boerhaave had misunderstood or misrepresented Steno's myology. Nevertheless Gosch remained critical of Steno's structural description quoting von Haller, that "muscles cannot in fact according to their structure be reduced to such a normal figure."[94]

Gosch's objection was repeated by Vilhelm Maar when he edited Steno's scientific works, the OPH, for publication in 1910. Maar considered the myology to be, "perhaps the weakest in his writings."[95] Later, in 1950, Eyvind Bastholm repeated Gosch and Maar's findings.[96] In 1986, Harald Moe, professor of anatomy (and among my own teachers as a medical student) formulated objections similar to Maar's to the anatomical foundations of Steno's description of muscle threads formed in a parallelepiped.[97] Six years later, however, in an English translation, Moe revised this own previous judgment: "Recently researchers in America and Holland have documented that both Steno's starting-point and his thesis were correct, and nowadays his muscle model has become part of computer trials and analyses in modern research on muscles."[98]

In 1997, it came to my attention that a second researcher was on the same track. Margaret A. Nayler had defended a PhD dissertation, *The Insoluble Problem: Muscle in the Mid- to Late Seventeenth Century*, at the University of Melbourne, Australia in 1993. Independently, we had analyzed works by the same authors on muscle and come to much the same conclusions on fibre shortening and on the reception of Steno's myology. Hence, Nayler wrote, "there seems to have been a reluctance or even inability to accept that shortening of the fibres could occur without their inflation."[99] Indeed, until the last decades of the twentieth century eminent scientists and commentators still rejected Steno's myology perpetuating centuries of unfounded critique.

From investigations made to improve orthopedic tendon repair in humans, researchers in several countries showed in the 1980s that the macro-anatomy

94 Gosch, *Udsigt over Danmarks Zoologiske Litteratur* (1873), Part II, vol. I, pp. 149–256.

95 Maar, "Life and Works of Nicolaus Steno," in OP I, p. XVIII. Maar held a D.Sc. in physiology which gave credibility to this assessment.

96 See Bastholm, *The History of Muscle Physiology*, pp. 142–163.

97 Moe, *Niels Stensen, En Billedbiografi*, p. 100.

98 Moe, *Nicolaus Steno, An Illustrated Biography*, p. 100. These statements reflect a change of mind by the author based on a single reference (see Kardel, "Niels Stensen's geometrical theory of muscle contraction (1667)," pp. 953–965).

99 Nayler, *The Insoluble Problem*, p. 276. See also generally the chapters on Croone (pp. 146–224), on Steno (pp. 226–286), and on Borelli and Bernoulli (pp. 453–554).

of skeletal muscles in man and in many animal species is often built from uniform parallel muscle fibres with an angle towards parallel tendon plates as displayed by Steno.[100] That is just the *structural* foundation of Steno's model of the contracting muscle. Fibre shortening, the *functional* element, had already become commonplace knowledge from microscopic and electrophysiological experiments by the end of the 18th century.

During the 1980's, the biomechanics of muscular length/strength effects was reformed partly based on new computational techniques, partly from taking into use the reintroduced pennate structure of muscle from the measurement of average fibre lengths and pennation angles in a number of skeletal muscles in man and animals.[101] The functional characteristics of muscle fibres and the pennate structure of muscle architecture were written into computer programs.[102] These and other studies pragmatically confirmed Steno's geometrical model. Drawn as a parallelogram, the unipennate model by Hoy, Zajac and Gordon (Fig. 6.7) mirrors Steno's sketches (compare with Fig. 6.1 and 6.3 above).[103]

100 See Brand et al., "Relative Tension and Potential Excursion of Muscles in the Forearm and Arm," p. 212: "With remarkable insight, Nicolaus Steno described the geometry of muscle fibers in 1667. His diagrams, though somewhat simplified, gave a clear picture of the way a series of muscle fibers join a tendon, and the way in which the tendon becomes progressively thicker as it accepts more and more fibers." See also An et al., "Muscles across the Elbow Joint," pp. 659–669. For an *in vivo* representation of Steno's parallelogram of muscle in relaxation and contraction produced by ultrasound technique, see Chow et al., "Sonographic studies of human soleus and gastrocnemius muscle architecture," p. 239, fig. 4. The figure shows how the pennation angle in the muscle changes approximately from 15° to 35° when contracted. In Steno's illustration of gastrocnemius muscle, possibly drawn from a muscle with *rigor mortis*, the pennation angle is approximately 35°.

101 See Wickiewicz et al., "Muscle architecture of the human lower limb," pp. 275–283; and Lieber and Blevins, "Skeletal Muscle Architecture of the Rabbit Hindlimb," pp. 93–101.

102 See Huijing, "Architecture of the Human Gastrocnemius Muscle," pp. 101–107; Otten, "Concepts and Models of Functional Architecture in Skeletal Muscle," pp. 89–137; Hoy et al., "A Musculoskeletal Model of the Human Lower Extremity," pp. 157–169; Lieber et al. "Model of Muscle-Tendon Interaction During Frog Semitendinosis Fixed-end-contractions," pp. 421–428; and Zajac, "Muscle and Tendon," pp. 359–411.

103 This illustration was chosen among sketches in 11 studies from different groups 1984–1992 listed in SOM, p. 49, all of them showing resemblance with Steno's representation as displayed in Fig. 6.3 above. Hoy et al., "A Musculoskeletal Model," pp. 157–169. In 1990, I concluded that anatomical and biomechanical studies published after 1980 show that the foundation and applicability of Steno's myology are still valid. See Kardel, "Niels Stensen's geometrical theory of muscle contraction (1667)," p. 953.

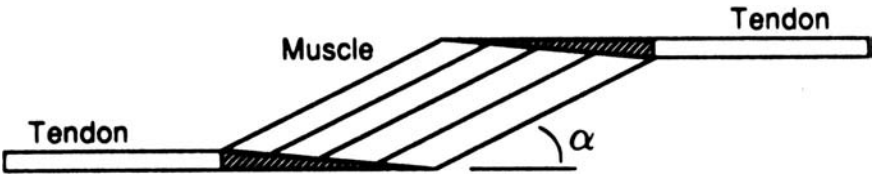

FIGURE 6.7 *Schematic representation of a musculotendon actuator being part of a model for simulation studies in Hoy et al. "A Musculoskeletal Model," Fig. 1*

Increased computational power has enabled researchers to equalize intramuscular pressure[104] or to take into consideration the length/force effects of myofascial transmission.[105] Steno's basic elements have subsequently become a paradigm onto which more elements are added in the programs, while the basic elements are less visible in the written reports than just few years earlier. Steno's geometrical model of muscle contraction as published in 1664 and 1667 has stood its test against centuries of attempted refutation and become part of mathematics in computer-models simulating locomotion with predictive value, benefitting health-care, sport, and animation of movements.[106]

7 Conclusion: Steno's Way of Reasoning

Steno described the purpose of his project on muscle as follows:

> I wished to demonstrate in this dissertation that unless myology becomes a part of mathematics, the parts of muscles cannot be distinctly designated nor can their movement be successfully studied. And why should we not give to the muscles what astronomers give to the sky, what geographers to the earth, and, to take an example from microcosm, what writers on optics concede to the eyes?[107]

His project thus consisted in using mathematics, and geometry in particular, to support plausible hypotheses about structures and functions of muscle that were not directly visible or measurable. Steno's muscle theory was, however,

104 Van Leeuwen and Spoor, "Modelling Mechanically Stable Muscle Architecture," pp. 275–282.

105 Yucesoy et al., "Effects of Inter- and Extramuscular Myofascial Force Transmission on Adjacent Synergistic Muscles," pp. 197–811.

106 Kardel, "A Biomechanical Revolution," p. 777.

107 KM, p. 547.

just one among other theories where he described mechanisms and processes that could not be directly observed, or only observed partially, by means of hypotheses allowing him to fit them into larger sequence of events.[108] Regardless of their origin, Steno excluded explanations when he found them wrong or inadequate. He was an outspoken self-critic. He gives a glimpse of his method in 1662:

> Since I had described everything historically [*historice*] in the *Disputatio de Glandulis oris & nuper observatis inde prodeuntibus vasis prima*, it remained for me to add something about the function. Hence I added a *second* discussion in wherein, straight away from the beginning, I presented what resulted spontaneously from the observations that *the task of the glands is to prepare this humour, which is always found in the mouth*. I also added examples to show that one has not to resort to other paths to let down saliva directly in the mouth. It remained to be determined whether the saliva would have to be led indirectly, which is very questionable.[109]

Without direct observation being possible he hypothesized that saliva, tears and milk were supplied to the secretory vessels in glands from the arterial blood under the control of the nerves. Tissue dissections allowed him to exclude other sources such as that tears stem from the brain, saliva from the gullet and milk from chyle (the fatty milk-like lymph of the gut).

Likewise Steno's work on earth science includes important clues to understanding his general scientific method. Hence, in *Canis Carchariae Dissectum Caput*, he presented the biological origin of fossils in the form of six consecutive *conjecturae*.[110] According to these, stratified rocks are deposits from a sea that earlier covered the place. But no one can observe a process that was completed in the past, so Steno attempted to build and confirm his "conjectures" regarding past events by means of observable consequences. A small remark tells about this procedure. Considering the precipitation of solids from crystals, he exclaims, "How well then everything fits together! How unanimously they come together in agreement!"[111] Mutually supportive observations and the

108 Kardel, "On Deducing the Unobservable." Paper presented at the meeting of the Geological Society of America in Baltimore, 2 November 2015, https://gsa.confex.com/gsa/2015AM/webprogram/Paper260257.html (link to the PowerPoint presentation).

109 KM, pp. 400–401 (translation altered).

110 KM, pp. 386–595.

111 KM, 5th Conjecture, § 4, p. 591.

absence of contradicting observations brought a form of certainty to his claims. Nonetheless, Steno's geological theories, just like his myological ones, became the object of fierce dispute.[112] The hypothetico-deductive method constituted Steno's basic research tool from his earliest to his latest investigation.[113] With cumulated evidence his deductions became basic theories if not just common knowledge.

The construction of concepts based on a combination of observation and reasoning was also a theme in the *Prooemium demonstrationum anatomicarum in Theatro Hafniensi Anni 1673* where he states this general principle: *"Pulchra sunt qvæ videntur, pulchriora qvæ sciuntur, longè pulcherrima qvæ ignorantur."*[114] What is "hidden", i.e., what geometrical reasoning adds to sense knowledge, is "even more beautiful" than what appears to the unaided eye: "Every muscle swells when contracting." What is then "the most beautiful by far"? For Steno it was "what we do not know." He left it to the reader how to interpret this often quoted assertion.[115]

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112 See Cutler, *The Seashell on the Mountaintop*, pp. 123–139.

113 Kardel, *Steno—Life, Science*, p. 74. See also Andrault, "Mathématiser l'anatomie," pp. 512–513; and Hansen, "On the Origin of Natural History," pp. 159–178.

114 Steno, *Prooemium* (1673), transl. in Kardel, *Steno, Life, Science, Philosophy*, pp. 120–121. See also the handwritten account by Holger Jakobsen (Jacobæus) of the "Preface" (*Prooemium*) and of the subsequent dissection, included in ibid., pp. 128–146.

115 This paper is based on the *Steno Prize Lecture* at The Danish Biomechanical Society in 2013 and a paper presented at the conference *Steno and the Philosophers* at the *Institut des études avancées de Paris* in February 2015. I am grateful to the organisers and editors Raphaële Andrault and Mogens Laerke for the invitation to present this paper. They found the right time for the right idea. The author wishes to express his gratitude for input and inspiration from Margaret Ann Nayler (South Yarra, Victoria, Australia), Professor John Heng (UWO, London, Ontaria, Canada), and Dr. Paul Maquet (Aywaille, Belgium).

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PART 3

The Natural History of the Earth

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CHAPTER 7

Thinking from Traces: Nicolas Steno's Palaeontology and the Method of Science

Justin E.H. Smith

1 Introduction

In this article I offer an interpretation of Steno's principle contributions to the methodology of geology, and I attempt to position these contributions in relation to his broader natural-philosophical and theological commitments. I argue against the common view that he had been an eager adept of natural philosophy in his earlier life, only to radically abandon this interest upon conversion to an austere version of Catholicism. Rather, Steno's investigations in geomorphology are the natural outgrowth of an earlier and consistent theological interest in the biblical account of creation. His lasting contribution to geology was his adoption of a form of reasoning, close to what C.S. Peirce would later call "abduction," that is particularly appropriate to any domain of inquiry concerned with past processes. In this way Steno established geology as a historical science, which it would remain through its full development into a mature science in the work of Charles Lyell. Throughout his career, Steno was concerned with how the unknown comes to be known, and above all with the problem of the knowability of the past. It is with respect to this latter problem that his work proved to be most useful, to the extent that he first saw the significant implication of the new mechanical philosophy for abductive reasoning about past processes: namely, that while we are able to 'read' the earth's past from its present state, the traces of the past here are a special kind of trace. They are vestiges of things themselves, rather than signs or representations of other things. This difference in turn illuminates a larger difference between the study of human history and the study of the history of the earth: a difference that does not so much make geology and history different sorts of inquiry, as rather different varieties of the same sort.

In the first section of this article I will examine the early development of Steno's thought, including the 1659 *Chaos* manuscript, looking particularly to understand the relationship between his interest in geomorphology on the one hand and his broader natural philosophical and theological commitments on the other. In the second section I will consider, with special attention to the

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work of not only Steno but also Lyell, the particular difficulties of the science that deal with past processes, in order to properly understand the significance of Steno's contribution to the methodology of such sciences. In the third section I will turn to a close study of Steno's 1669 *Prodromus to a Dissertation on Solids within Solids*, looking also at the earlier geological and paleontological studies that precipitated it. Finally, in the fourth section, I will attempt to discern the fixed points of orientation in Steno's career, from the *Chaos* to the post-conversion anatomical studies, arguing that throughout his work he is motivated by an inclination to a sort of mythopoetic speculation, which sustains an inevitable ambivalence in him with respect to the category of "the unknown." I will conclude with some brief observations about the significance of Steno's work for our understanding of the sciences that deal with past processes, and about the possibility they might hold out for reunifying the study of both human and natural history.

2 *Chaos*

Nicolaus Steno is rightly hailed as one of the most important figures in the foundation of geology as a science. His most noted contribution was the correct identification of what had previously been called *glossopetrae*, or "tongue stones," as sharks' teeth. But behind this discovery lay a far more important innovation in methodology: he innovated the principles for establishing the origins of geomorphological features, including fossils, but also minerals, gems, and sedimentary strata, from past processes. In effect, he figured out how to read the past of the earth from present traces.

His principal insight was to notice that there are features of the earth's surface, and of the objects found in it, that tell the story of "before" and "after," that reveal the relative chronology of things. In particular, what is often called the "principle of moulding" tells us that wherever there are two contiguous solid bodies, the one that takes the shape of the other is the one that passed more recently from a liquid to a solid state. This principle, and the related principle of superposition (according to which lower strata may be known to be older than higher strata) are said to express the crucial doctrine of modern geology known as "uniformitarianism," which holds that the laws governing the past processes that led to the current conformation of the earth are the same laws that are governing current processes. The earth did not come to its current shape as a result of a single great catastrophe in the past, after which "nothing was ever the same." Rather, everything *is* the same, and in fact, to invoke the related doctrine of geological actualism, the past pro-

cesses are still ongoing, even if for the most part they are doing so gradually and imperceptibly.[1]

The principle of moulding is underlain by another commitment as well, which unlike uniformitarianism and actualism belongs not to the future science of geology, but to the long past of cosmogonical speculation. Namely, Steno is committed to the view that all things come from a single substance, fluid, or, rather, a rarefied form of fluid called *chaos*. The first significant occurrence of this term is in the Greek translations of the Hebrew book of Genesis, in which we learn that, at the Creation, "the Spirit of God moved upon the face of the waters" (1:2). The term *chaos* does not occur in the Greek Septuagint, yet there is a long tradition linking it to the Hebrew phrase וָבֹהוּ תֹהוּ ("shapeless and formless") in the original Hebrew, which in turn seems to be a characterization of the condition of the "waters" prior to God's creation of light in Genesis 1:3. It is this Greek cosmogonical concept that Jan-Baptista Van Helmont wished to invoke when he coined the new term "gas" in his 1648 *Ortus medicinae*.[2] Of course the Belgian chemist and natural philosopher was in the course of discovering a separate state of matter, but in early usages of this term it is not yet plainly distinct from the fluids of which it is conceptualized simply as a somewhat more rarefied form. Van Helmont also believed that everything in nature is a transformation of water, and sought to establish this empirically by an experiment involving the growth of a willow tree over several years, while regularly watering it and adding virtually no new soil to its pot. So for Van Helmont the primordial stuff from which all nature may be derived is fine atmospheric water, which is both evoked in Genesis as Chaos, and which is, equally, established in experience.

The young Steno, as a student in Copenhagen, is enthusiastic about the chemical work of Van Helmont and his 16th-century predecessor Paracelsus, while at the same time taking an interest in the newer geometrical philosophy promoted by Descartes. His earliest known writings are a notebook filled with scattered comments on natural philosophy dating from 1659, to which he himself gave the title *Chaos*.[3] Discovered by Gustav Scherz only in 1946, this manuscript gives us important insight into Steno's development as a thinker. In particular, we see that from the beginning Steno's interest in natural philosophy, far from standing in conflict with his religious faith, was in fact motivated and informed by this faith. Steno remarks that "in Holy Scripture it is

1 See Bülow, "Steno's aktualistisch-geologische Arbeitsweise," pp. 149–162.

2 Helmont, *Ortus medicinae* (1652; 1st ed. 1648), p. 59: "[I]n nominis egestate, halitum illum, Gas vocavi, non longe a Chao."

3 Steno, *Chaos. Niels Stensen's Chaos-Manuscript*.

said that the world has come forth from 'unseen' matter as from chaos."[4] This insight, which is surely not original with him, is in turn supported by numerous observations coming from the work of Van Helmont, Athanasius Kircher, Pierre Gassendi, and others. His intellectual orientation and range of interests is in fact fairly similar to that of at least the first two of these figures: speculative, somewhat mystically inclined, and at the same time keen on absorbing the latest lessons from empirical natural philosophy, including Bacon, Descartes, and others,[5] even when these come from thinkers who do not share the same mystical and theological concerns. These preliminary observations are important for understanding the true character of Steno's supposed eventual repudiation of natural philosophy in favour of religious faith. This radical change is supposed to have been precipitated by his 1667 conversion to Catholicism. For Steno it cannot simply have been, however, that there was an unbridgeable rift between the aims and methods of natural philosophy and the life of faith, since it was a variety of faith that gave shape to the natural philosophy in the first place.

Another enduring feature of Steno's work in natural philosophy was to determine the usefulness of explanatory strategies taken from the organic realm for application in the inorganic realm, and vice versa. In other words, if we may permit ourselves some anachronism, he was interested in determining the extent to which "biological" explanations are useful for "geology," and vice versa. In the early work there was a presumption of the broad unity of the two domains and a cautious support of the doctrine of "geocosmism," an approach to geology that takes the earth as a single organism, and sees geological entities as generated in the same way living beings are, rather than as the result of the operation of heat and external forces on passive matter.[6] On this view, gems and minerals are brought forth in the 'bowels' or 'womb' (variant translations of *matrix*) of the earth.

This doctrine is not so important for our present concerns, but what is interesting is that the presumption of unity between these two domains enabled Steno, in the *Chaos* manuscript, to discern within the human body an instance of the general Helmontian and biblical principle according to which all things are transformations of water. That instance, namely, was the generation of stones in the organs and ducts of the body, presumably as accretions of trace

4 Ibid., p. 435. See also Rosenberg, "Nicholas Steno's *Chaos* and the Shaping of Evolutionary Thought," pp. 793–796.

5 On Descartes's influence in particular, see Olden-Jørgensen, "Nicolaus Steno and René Descartes."

6 On Kircher's geocosmism and its influence on the young Steno, see Yamada, "Kircher and Steno on the 'Geocosm'."

solids in the fluids these internal parts ordinarily host. Bladder or kidney stones do seem to provide compelling evidence that the body is indeed subject to the same laws as the earth. And since even the non-pathological generation of nails and bones in embryogenesis seems to show that solids regularly develop from liquids, it could easily have appeared a reasonable hypothesis of speculative geogony that every solid body in the world began in a liquid state. From here it was an easy step to Steno's first scientific publication, the *Dissertatio physica de thermis* [*Physical Dissertation on Thermal Baths*],[7] published in Amsterdam in 1660 shortly after his arrival there to study with his fellow Dane, the alchemist and natural philosopher Ole Borch.[8] In this concise work Steno seeks to account for how the water coming from thermal springs can contain such high levels of mineral substances that are ordinarily encountered in a solid state, but without making the water any less liquid. Correlatively, he wishes to show how mineral formations around thermal springs could themselves be accretions of formerly dissolved traces.

Steno would go on to write three more treatises of principally geological interest, as well as a few letters, composed in Italian, to the Grand Duke of Tuscany, describing caves in the region. After *De thermis*, seven years would pass in which Steno would concentrate exclusively, at least in his written work, on anatomical questions. In 1667 two separate studies appear together with the *Elementorum myologiae specimen, seu Musculi descriptio Geometrica* [*Specimen of the Elements of Myology, or A Geometrical Description of Muscle*]. The first is the *Canis carchariae dissectum caput* [*A Charcarodon Head Dissected*], and the second the *Dissectus piscis ex canum genere* [*A Fish of the Shark Species Dissected*].[9] The literal translation of "shark" here is "dog," and occasionally we see it rendered in English as "dogfish." This term is a curious relic from the history of taxonomy, but more curious still, perhaps, are the reasons for classifying these studies, evidently on straightforwardly anatomical subjects, as being of geological interest. The 1669 *De solido intra solidum naturaliter contento dissertationis prodromus* [*Prodromus of a Dissertation on Solids Naturally Contained within Solids*] will be, after the *De thermis*, the first published work devoted entirely to geological questions, but as Steno humorously explains there it was the coincidental encounter with the "dog" two years earlier that had impelled him to

7 Steno, *Disputatio physica de thermis* (1660).

8 For a fairly comprehensive presentation of Borch's principal contributions to natural science, with some indications of what his particular influence on Steno could have been, see Børge Riis Larsen, *Ole Borch (1626–1690): En Dansk Renæsancekemiker*.

9 Steno, *Nicolai Stenonis Elementorum myologiae specimen* (1667).

work on the problem of "solids within solids," which is to say of geomorphology. To cite the 1671 English translation, which captures Steno's humour more accurately than later renderings have:

> When I was upon giving a particular & minute account of the Muscles, I was taken off by a Dog of a prodigious bigness, which your Seas presented us with; And whilst I am altogether addicted to the present Experiments, I am called away by Him, whom the Law of Nature, and the great Favours conferr'd on me and mine, command and press me to obey.[10]

The head had been sent by the Grand Duke of Tuscany as a result of a fortuitous catch by a fisherman off the coast at Livorno. Though the animal was in many respects simply another in the long list of species on which Steno had performed anatomical studies by 1667, it also had a particular feature that made its study relevant to geology: its teeth, namely, resembled the stones commonly called *glossopetrae*, which had long been collected by naturalists in inland regions, and indeed resembled them so perfectly as to require explanation. Steno's mentor at Copenhagen, Thomas Bartholin, had collected *glossopetrae* during his trip to Malta in 1644, and we may assume that Steno was familiar with them during his student days. There were various accounts of these stones' origins, but the most common one was that they were the petrified tongues of giant vipers, or perhaps dragons—in any case of terrestrial creatures. Another very common view is that these seemingly organic traces were generated directly where they are found, as were the stony remains of fishes and other animals, as a result of the earth's over-productive power, its capacity to generate organic forms even where the matter is not conducive to hosting an actual living being. These misplaced forms are what were often described as *lusus naturae*, games of nature.

By 1667 Steno does not seem particularly attracted to Kircherian geocosmism. He does not think nature has the capacity to generate organic form, or in general that biological explanations are useful in accounting for geological entities. He does not seem to hesitate in concluding, based on his study of the

10 Steno, *The Prodromus to a Dissertation concerning Solids Naturally Contained within Solids* (1671), p. 6; Steno, *Nicolai Stenonis De solido intra solidum naturaliter contento dissertationis prodromus* (1669), p. 4: "Ne musculis minutim describendis inhererem, prodigiosae magnitudinis Canem tua Maria nobis obtulerunt; iamque totum deditum presentibus experimentis ad alia inuitat, cuus nutui obedire lex Naturae iubet, magna in me, Meosque promerita hortantur." For a revealing contemporary account of Steno's study, see Arbuthnot, *An Examination of Dr. Woodward's Account of the Deluge* (1697).

teeth in his own shark specimen's mouth, that glossopetrae, wherever they are found, are shark's teeth as well. But what seems to have become clear to him during this study, as he will fully articulate two years later in the *Prodromus*, is the need, in order for the domains of the geological and the biological to be accurately marked off from one another, to approach the study of the earth as fundamentally a variety of *historical* inquiry.

3 Knowing the Past

The division of the sciences that groups all inquiries focused on past processes together, regardless of whether they are concerned with the natural or the human domains, seems rather foreign to us today. Palaeontologists generally do not believe they have much in common with cultural historians (though archaeologists, perhaps, are exceptional in continuing to perceive the continuity between the natural and the social, constrained as they are to reconstruct the human past by studying, e.g., soil chemistry and skeletal taphonomy). For most of the early founders of geology, by contrast, not just in the early modern period, but indeed well into the 19th century, the connection was obvious. Thus in his *Principles of Geology* of 1830–1833, Charles Lyell describes this science as fundamentally historical, and as relating to the physical sciences in the same way that history relates to the moral sciences.[11] Just as "we obtain a more profound insight into human nature, by instituting a comparison between the present and former states of society," all the more "astonishing and unexpected," he writes, "are the connections brought to light, when we carry back our researches into the history of nature."[12]

The analogy between human history and geology can only be carried so far, however, since, as a result of human intention, many of the monuments of the human past are in fact distortions of the past. When human beings begin to keep their own records and tell their own stories, they are no longer as reliable as they had been when they were producing evidence of their activities in more or less the same way nature does. Lyell explains:

> The analogy, however, of the monuments consulted in geology, and those available in history, extends no farther than to one class of historical monuments—those which may be said to be *undesignedly* commemora-

11 Lyell, *Principles of Geology* (1858; 1st ed. 1830–1833), p. 2.

12 Ibid., pp. 1–2.

> tive of former events. The canoes, for example, and stone hatchets found in our peat bogs, afford an insight into the rude arts and manners of the earliest inhabitants of our island; the buried coin fixes the date of the reign of some Roman emperor … This class of memorials yields to no other in authenticity, but it constitutes a small part only of the resources on which the historian relies, *whereas in geology it forms the only kind of evidence which is at our command*. For this reason we must not expect to obtain a full and connected account of any series of events beyond the reach of history. But the testimony of geological monuments, if frequently imperfect, possesses at least the advantage of being free from all intentional misrepresentation.[13]

Here Lyell offers a fascinating inversion of our ordinary expectations of the accessibility of different sorts of traces of the past. The "monuments" of past geological processes were never meant to communicate information to us, but it is this very lack of intentionality that ensures that they cannot deceive us. Those human monuments that are most reliable are the ones that belong not so much to history as to prehistory, and to the traces of material culture that remain fundamentally the same after the passage from prehistory to history with the advent of writing: the portion of the human past, namely, of which we know only by accidental traces rather than conscientious record-keeping. This is important, as it shows that one of the reasons why it has become more difficult to think of geology as history, since the time Lyell was writing, is that we have also cordoned off human history from human prehistory, and tend to think of the discipline of history as involving only the study of intentional traces, which is to say of texts.

These considerations will be important for us when we return, towards the end of this article, to the relationship between natural philosophy and scriptural revelation for Steno. For now it is only important to stress that on Lyell's conception the discipline of geology is conceived with maximal breadth, as "the science which investigates the successive changes that have taken place in the organic and inorganic kingdoms of nature."[14] It is not the study of "rocks," but rather the study of terrestrial nature as a whole, in the aim of accounting for the past processes that brought nature to its present point. This capacious understanding of the scope of geology can help us to understand Steno's own easy motion from one sort of study to another very different sort, on the

13 Ibid., pp. 2–3.

14 Ibid., p. 1.

occasion of the delivery of the shark's head. Lyell himself describes Steno's *Prodromus* on "solids within solids," which he says bears a "quaint" title, as being concerned with "Gems, Crystals, and organic Petrifactions inclosed within solid Rocks." Lyell notes that when Steno was active, "[i]t was still a favorite dogma, that the fossil remains of shells and marine creatures were not of animal origin," and he takes this belief as a result of the superstitious reluctance of many to accept "that the earth could have been inhabited by living beings before a great part of the existing mountains were formed." Lyell suggests that it was "[i]n reference to this controversy" that

> Steno had dissected a shark recently taken from the Mediterranean, and had demonstrated that its teeth and bones were identical with many fossils found in Tuscany. He had also compared the shells discovered in the Italian strata with living species, pointed out their resemblance, and traced the various gradations from shells merely calcined, or which had only lost their animal gluten, to those petrifactions in which there was a perfect substitution of stony matter. In his division of mineral masses, he insisted on the secondary origin of those deposits in which the spoils of animals or fragments of older rocks were inclosed.[15]

For an object to be "of secondary origin" in Lyell's sense is simply to have become a solid after the solid body in which it is contained, to be a younger solid within an older solid as a result of the replacement of "glutinous'" material by petrous material that takes the same form. Steno's title is perhaps not so much quaint as incomplete: it fails to convey the principal insight of the work, that the containment relation in question is also a key to the establishment of relative chronology.

For all its problems as a work of triumphalist history of science, Stephen Jay Gould's 1984 essay on Steno does help to clarify the true significance of the Danish philosopher's contributions. Steno's genius, according to Gould, "lay in recognizing that a solution to the general problem of how solid bodies get inside other solids might provide a criterion for unraveling the earth's structure and history."[16] This would be the case not just for fossils, but also for crystals, rocks, strata, in general for everything solid. Steno's new classification system for solids, as developed in the *Prodromus*, is based on grouping "by common

15 Ibid., p. 23.

16 Gould, "The Titular Bishop of Titopolis," p. 70.

genesis, rather than superficial similarity of outward appearance."[17] The basis of the claim of common genesis is the principle of moulding, which asserts that whenever we find a solid within a solid,

> we can tell which hardened first by noting the impress of one object upon the other. Thus, fossil shells were solid before the strata that entomb them because shells press their form into surrounding sediments … But surrounding rocks were solid before the calcite veins that run through them because the calcite fills preexisting channelways just as Jello matches the flutes of a mold.[18]

In Steno's own words, the principle holds that "if a solid body is everywhere encompassed by another solid body, that of the two was hardened first, which in the mutual contact exhibits on its surface the properties of the surface of the other."[19] Of course, the sort of inference allowed by this principle is not without its epistemological worries. These are the same worries doubters of evolution today continue to invoke when they suggest that because we were not there, and could not witness what was happening, evolutionary theory cannot be considered an empirical science. It is moreover argued by these doubters that we have no clear idea of what a falsification in evolutionary theory might be, since by definition it concerns matters that have already happened. There are various compelling responses to these worries. One is that evolution *can* in fact be witnessed 'in action', as for example in the case of rapid adaptations in the generations of *Drosophila* fruit flies studied in laboratories. And even with respect to claims about the past, many have argued that we can in fact imagine new discoveries that would amount to falsifications of the theory, as for example J.B.S. Haldane's well-known figure of the pre-Cambrian rabbit fossil. It is difficult to imagine, for Steno, what sort of possible observations might be comparable to the fruit flies evolving in real time or to the out-of-place rabbit fossil, and for this reason we are confronted with the problem, no small one for understanding the history of science, of the speculative character of his insight. That is, we seem to be confronted with the possibility that the progress Steno made in the study of the earth was in fact made by detaching his claims

17 Ibid. p. 73.

18 Ibid. p. 74.

19 Steno, *Prodromus*, p. 15: "Si corpus solidum alio corpore solido vndique ambitur, illud ex iis primo induruit, quod in mutuo contacto sua superficie alterius superficiei proprietates exprimit."

from the safe realm of the observable, and holding forth on what happened long ago, in a time to which many contemporaries believed only revelation could give us access.

There is of course no firm boundary between the speculative and the well-founded, and in many sciences a speculative theory can be put forth at one point, that will later become well-founded as a result of the accumulation of supporting observations and evidence. Kant's nebular hypothesis is a good example of such a theory. Whether a given scientific theory is speculative or not at a given point in its development also depends to no small extent on whether one is a defender of that theory or not. Most cosmologists believe that the Big Bang theory is now well-founded, yet there are dissident views according to which this account of the origins of the universe involves cosmologists going beyond the bounds of their true expertise in order to speculate on what *might* be the case. A somewhat more controversial case, already invoked, is mounted by the "creation scientists" who claim that evolution is "just a theory." Most of us suppose by contrast that to be a theory is not in itself a bad thing, and that Darwin largely succeeded in making evolution a well-founded theory, as opposed to a "mere" theory, to the extent that he identified a mechanism, natural selection, that made appeal to the descent of present species from past ancestors the most reasonable way of accounting for how the past relates to the present state of things.

Steno's contribution to geology was similar: he identified principles that made a particular account of past geological processes the most rational and compelling one to accept. These principles do not permit us to go back and witness the past, any more than Darwin's theory of natural selection enabled him to travel back in time, but they do allows us, by deploying a sort of reasoning akin to what C.S. Peirce would later call "abduction," to make inferences to the best explanation in a way that makes further suspension between alternative accounts irrational. For Peirce, "[a]bduction is the process of forming explanatory hypotheses. It is the only logical operation which introduces any new idea."[20] He believes that abduction gives us a clue to what might have been the case, but does so in a different way than induction's delivery of probabilities concerning hypotheses we have already formed prior to our setting out to investigate. While inductive inferences move from a case to a result and then, finally, a rule, abductions move from a rule to a result, and then, finally, a case.

20 Peirce, *Collected Papers*, vol. 5, p. 172. For an earlier, enlightening account of Steno's method as essentially Peircean and abductive, see Baker, "Charles S. Peirce and the 'Light of Nature.'"

Thus the classical example gives us the rule that "All the beans from this bag are white," the result that "These beans are white," and the concluding case, which asserts that "These beans are from this bag." Applied to a case of interest to Steno, we might say he reasoned as follows:

> All shark's teeth have such-and-such form.
> These *glossopetrae* have that same form.
> These *glossopetrae* are in fact shark's teeth.

We are not only far from the realm of certainty here, but even from the realm of asymptotic approach toward sympathy through the accumulation of further instances. Like deduction, abduction is not strengthened by subsequent cases. Unlike deduction, the inference established from an initial case is not certain. Unlike the uncertainty of induction, moreover, the initial inference is, so to speak, as good as it gets.

What makes some abductive inferences "feel good," for some, in turn depends on philosophical commitments. What were the commitments that made Steno's account of the earth's past compelling? Here it will be helpful to recall Lyell's account of the limits of the comparison between history and geology. For Lyell, human traces are certain when they are *undesignedly* produced. Only a small subset of such human traces are of this sort, whereas all the productions of nature are. Here Lyell is on one side of a sharp divide, not initiated, but certainly deepened, by Steno two centuries before. On this side, nature is fundamentally unlike humanity to the extent that it is not capable of "authorship." The traces it produces can thus not be signifiers or likenesses of things, but can only be vestiges of the things themselves. This commitment is in turn a reflection of very broad transformations in the philosophy of nature that took place in the 17th century, of which Steno's account of solids within solids is a sort of concrete and narrow application. No one summarizes these transformations more succinctly or evocatively than G.W. Leibniz, who under the influence of Steno's work would write in his *Protogaea* of the 1690s: Nature does not play.[21]

21 See Leibniz, *Protogaea*, esp. § 10.

3 Signs and Vestiges

The varieties of play Leibniz has in mind here are imitation, aping, parroting, or "counterfeiting" in the early modern sense, in which an illustrator may be said to "counterfeit" a leaf, to *make* a new leaf, or at least a reflection of one, *against* the model of a real leaf. Authors, too, the producers of the texts that constitute 'history' in the narrow sense bracketed by Lyell, "counterfeit" the world, create a reflection of the world that is ontologically distinct from it and yet harmonized with it. But this is something that nature itself can no longer do. Nature cannot be a book, to cite the common Renaissance trope, since its productions are not signs or reflections or counterfeits, but rather are the original source of these. The reason why nature can no longer play in any sense, including the imitative one, is of course that it operates without intention, "unguidedly." But this, as Lyell saw, is the same thing that makes its traces certain. Here it will be helpful to introduce a technical distinction. Traces that are vestiges, we might say, are traces of the things themselves, and to identify them as such is only to establish identity, while traces that are signs require interpretation as to the meaning and causes of the resemblance. In this respect geology, as the history of nature, though abductive, nonetheless affords us a sort of certitude that is generally impossible in human history.

On Gould's reading, after moulding, the second principle Steno introduces is the one that gives an account of how, "Given a substance possessed of a certain figure, and produced according to the laws of nature," we may "find in the substance itself evidences disclosing the place and manner of its production."[22] And Steno's answer is this:

> If a solid substance is in every way like another solid substance, not only as regards the conditions of its surface, but also as regards the inner arrangement of parts and particles, it will also be like it as regards the manner and place of its production.[23]

According to Gould, Steno's great insight is that, if we wish to infer the past processes that formed a given geological object, we must look to "the object itself." The "surest clue," he explains, is similarity to "modern objects," not just

22 Gould, *Hen's Teeth and Horse's Toes*, p. 75.

23 Steno, *Prodromus*, p. 16: "Si corpus solidum alii coropori solido, non modo qua superficiei conditions, sed etiam qua intrinsecam partium particularumque ordinationem, per omnia simle fuerit, etiam qua modum, & locum productionis illi simile erit."

as a whole, but rather "part by internal part."[24] This is a principle that Steno clearly articulates already in the *Carcharodon Head Dissected* of 1667:

> The bodies resembling various parts of aquatic animals, whether they are dug out of hard or soft soil, resemble exactly not only each other, but also the parts of the animals to which they correspond; and there is no difference at all in the course of the stripes, in the structure of the lamellae, in the windings and bulges of the cavities, in the joints and hinges of the mussel shells.[25]

This is precisely the sort of reasoning that G.W. Leibniz would later adopt in the *Protogaea*, against the "supposed likenesses of fish" in stone:

> Their fins and scales are reproduced with so much precision, and the multiplicity of these images in one place is so great, that we are more inclined to presume a manifest and constant cause than a game of hazard, or I-know-not-what generative ideas: empty names behind which the ignorance of the philosophers hides.[26]

Leibniz mentions the example of likenesses of Christ or of the Virgin often discerned in rock outcroppings, or the small figurines of miners often found by miners themselves. If these were more than just likenesses, then we would expect to find more correspondence of detail, the closer we look, whereas in fact the more carefully we inspect the more the likeness fades. This, then, might be a sort of empirical test, and one that can be run over and over for inductive corroboration: each time an anthropomorphic likeness appears in stone, it fails upon closer inspection. Each time an ichthyomorphic one appears, by contrast, closer inspection only strengthens the initial hypothesis that we are in the presence of a true vestige of a fish. Organic traces always reveal their

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24 Gould, *Hen's Teeth and Horse's Toes*, p. 75.

25 Steno, *The Earliest Geological Treatise (1667) by Nicolaus Steno*, p. 11: "Corpora variis aqvatilium animantium partibus similia, sive duriori, sive molliori e terra eruta, non modo sibi invicem, sed etiam animalium partibus, qvibus respondent, simillima sung; nec ulla est in striarum ductu, in lamellarum textura, in cavitatum gyris anfractibusqve, in bivalvium commissuris & cardinibus differentia."

26 Leibniz, *Protogaea*, sect. 28: "Tanta piscium simulatorum cum veris convenientia est, pinnis ipsis squamisque ad minutias usque expressis; tantaque imaginum frequentia in eodem loco visitur, ut manifestiorem constantioremque causam suspectemus, quam aut casum ludentem aut seminales, nescio quas ideas, inania philosophorum vocabula."

original organic character on investigation; likenesses, or counterfeit traces, only appear as such at a certain level of focus.

In the 1667 treatise Steno provides a further argument for the organic origins of fossil traces, one that Gould does not notice. It comes from a comparison between the high degree of order in organic traces, compared to the sort of order we see in the mineral realm:

> As to the form of the bodies of which we are speaking, since it corresponds exactly to the parts of animals, the similarity of the form seems to argue a similarity of origin; nor is it easy to believe, no matter in which other way you will contend that they have been made, that so great a similarity could have been found. And here is the clearest proof of this. Who does not admit that the hexagonal shape of rock crystals, the cubes of pyrites, the crystals of salt from chemical experiments and countless other bodies precipitated from liquids have shapes far more regular than mussel shells, oyster shells, conches and others? None the less, in these simple bodies we find now the top of the crystal cut off, now several bodies clinging together without order, now planes that differ from each other in size and position, and other various ways in which they differ from the usual shape. How much larger and more frequent defects should then be seen in the bodies of a much more composite shape, such as those that imitate the parts of animals?[27]

Even in the production of relatively simple mineral forms in nature, things never go smoothly: circumstances of the environment get in the way, impede the smooth and regular expansion of the same form in an orderly and predictable way. Similarly Leibniz will later argue that in the case of organic traces

27 Steno, *Early Geological Treatise*, pp. 37–39: "Qvod figuram corporum spectat, de qvibus agimus, cum animalium partibus qvam exactissime respondeat, conformationis similitudo originis similitudinem inferre videtur; nec facile creditu est, a qvocunqve demum principio alio facta illa dicas, conformitatem tantam fuisse observandam. Et exxe ejus rei evidentissimum argumentum. Qvis non agnoscit, hexaedram crystalli figuram, marcasitarum cubos, salium in Chymicis operationibus crystallos & infinita alia in fluido concerscentia corpora figuras habere multo magis ordinatas, qvam sunt figurae pectinum, bivalvium, turbinum aliorumqve? Nihilominus videmus in simplicibus hisce corporibus modo anguli solidi apicem truncatum, modo plura sibi sine ordine adhaerentia corpora, modo magnitudine & situ inter se differentia plana, aliosqve varios modos, qvibus a solita figura recedunt. Qvanto majores pluresqve notandi essent defectus in corporibus figuram multo magis compositam habentibus, qvalia sunt illa, qvae animalium partes imitantur?"

> it is not at all a matter of certain radial bodies and of regular polygons, such as crystals and garnet present us with; and the other gems and fluorites, as well as other diverse minerals, no more than in the case of hexagonal snow … It is not at all a matter of that geometry of inanimate nature, of which we can very easily make sense by means of the juxtaposition of parts, as in crystallization.[28]

Leibniz does not focus here, as does Steno, on the irregularities that typically arise in the growth of minerals and crystals, but the point is much the same: that organic traces cannot be generated directly out of the earth, as minerals and crystals are, because the latter sort of generation is more easily accounted for in terms of the mechanical forces of external pressure and of accumulation of matter, which then gets distributed according to geometrical principles, while nonetheless, as Steno stresses, being subject to the particular disordering factors of any given place.

Organic bodies, and the traces they leave, cannot possibly be accounted for in this way, but instead presuppose a pre-existing being, which either must be generated from a seed or germ, or, on Leibniz's account (which we needn't address here) have always existed.[29] Here, then, is precisely the ontological difference between living beings and the rest of nature that will much later animate Kant's distinction in the 1791 *Critique of the Faculty of Judgment* between, on the one hand, the snowflake, which, he says, needs no soul in order to take the shape it has, and, on the other hand, the blade of grass, for which, he says, there will never be an Isaac Newton to account exhaustively for its origins and structure. The same ontological distinction can be discerned abductively in the traces of organic beings as well: a crystal presupposes no work of an internal principle of development or of the flourishing of an organic body; a fish fossil, by contrast is a vestige of past vitality.

In the 1667 dissection of the shark's head, Steno is cautious. He defends the account of *glossopetrae* as shark's teeth, while also averring that he could be wrong, and promising to consider the opposing view in the future. He explains his approach through a comparison to the legal profession:

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28 Leibniz, *Protogaea*, p. 28: "Nam removere hinc oportet radiata quaedam corpora polygonorumque figuras regulares in crystallis, in granato, in reliquis gemmis et fluoribus, et variis mineris; tum in sexangula nive, in apum alveolis; in vitriolo etiam et alumine, et communi sali, nitroque […] caeteramque omnem naturae inanimae geometriam. Etenim haec externis appositionibus commode explicantur, ut in crystallismo."

29 See Smith, *Divine Machines*, esp. chapter 3.

> Thus just as in legal affairs, one takes the part of the plaintiff and the other submits himself to the decision of the judge, so I produce, from what has been observed in the past, the proofs of those who reckon those bodies to be of animal origin, setting down perhaps at another time the reasons for contrary opinions, and looking always for a true judgment from more learned men.[30]

Steno goes on to invoke a straightforward inductive basis for his treatment of the *glossopetrae* as shark's teeth, thus somewhat contradicting his claim that it is simply an arbitrary choice to take up the role of *advocatus diaboli* in opposing the view that the earth itself has generative power. He acknowledges that "some would have it that bodies dug from the earth bearing a resemblance to parts of animals are the remains of animals that were formerly in those places and are now decayed," while others by contrast "believe them to have been produced in the same places without animals being involved." For his part, Steno admits:

> I do not yet have the knowledge of this matter to pass judgment on it here; and though my travels have taken me through various places of this kind, nevertheless, I do not dare to guarantee that what I shall observe in the rest of my journey will be similar to what I have observed up to now; chiefly, since I have not yet seen what my very famous teacher Bartholin observed in his journey to Malta.[31]

By the time of the *Prodromus* two years later, Steno is much more committed to what had in 1667 been mere conjectures, and indeed devotes himself to proving, by a correct account of solids within solids, that what appear to be organic objects in the earth in fact are traces of organic beings. The *Prodromus* is written as a work preliminary to a future dissertation, which itself was never completed. And yet this prodrome is in itself a fairly systematic engagement with some of the questions addressed only tentatively in the 1667 study. In an otherwise insightful study, the historian Rhoda Rappaport complains of the *Prodromus* that "[t]he work is so abstract that it is virtually impossible to identify what terrains in Tuscany Steno actually examined."[32] But even if the treatise is geographically imprecise, its argumentative aims are rigorous and clear. Steno divides it into four parts:

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30 Steno, *A Carcharodon Head Dissected*, in KM, p. 585.

31 Steno, *Geological Papers*, p. 95.

32 Rappaport, *When Geologists Were Historians*, p. 100.

1. The "ancient, delightful, and useful question of sea objects at a distance from the sea."
2. Given a substance with a certain figure, and produced according to the laws of nature, how does one find in the substance itself evidence that discloses the place and manner of its production?
3. Various case studies of solids within solids.
4. The physical geography of Tuscany.

In the first section Steno identifies a significant difference between ancient and modern discussions of marine fossils on land. For the ancients the principal question was how the seashells arrived on land from the sea. But for the more recent authors, Steno maintains, the question has been what the seashells are. It is no longer taken for granted that they come from the sea at all. Some who denied "that the sea could ever cover the lands where they were found [...] employed their wit in extolling the powers of nature, as able to produce any thing whatsoever."[33] In Steno's view the problem of marine fossils on land has become more, rather than less, difficult for modern naturalists, as a result of the rise in recent centuries of erroneous theories of the earth's generative powers.

The second section of the *Prodromus* is certainly the one of most theoretical significance. He understands that in order to answer the rather narrow question of the origins of *glossopetrae* and similar bodies, an entire host of fundamental theoretical questions must be resolved as well: "[N]o one, in truth, will easily determine the place of production who does not know the manner of production, and all discussion concerning the manner of production is idle unless we gain some certain knowledge concerning the nature of matter."[34]

Steno is not interested in fossils in the narrow sense, but in all the traces in the earth that reveal something of past processes of formation. These include all those traces today called "ichnofossils": the fossilized remains of burrows, colonies, mounds, and other forms that animals have carved into the environ-

33 Steno, *Prodromus*, p. 7: "Antiquos vnica tantum exercebat difficultas; nempe quomodo res marinae in locis a mari remotis derelictae fuerint [...] Recentioribus seculis parcius vrgebatur Antiquorum difficultas, cum omnes fere circa ortum praedictorum corporum indagandum occuparentur; qui mari illa adscribebant, id agebant, vt ostenderent non potuisse id generis corpora aliter esse producta; qui terries illa attribuebant, negabant potuisse mare illa loca tegere, & toti in eo errant, vt Naturae parum cognitae vires laudarent aptas rebus quibuslibet producendis."

34 Steno, *Prodromus*, p. 9: "[...] & productionis modo vana est dissertation, nisi de materiae natura certam quamdam cognitionem habuerimus."

ment through their own activity. "The determination of natural motions can be altered," Steno explains, "[b]y the movement of living beings; and many of these things which in this way are produced by man, are said to be artificial."[35] Steno is often credited with the "discovery" of ichnofossils, though in truth his interest in them follows directly from his prior commitment to a broader conception of fossil than the one ordinarily employed today, which would take all traces of past activity of living beings, rather than just of their bodies, as being of interest for accounting for current geomorphology.

Steno argues that the current state of the earth arises from various combinations of three particular sorts of cause: (i) matter, (ii) motion, (iii) place. Those who believe that fossils are generated directly in the earth attribute the primary causal role to the last of these, to the special "petrifying virtue of the place," to use Kircher's terminology.[36] But Steno rejects this account, in large part because there is no evident reason why one place should have such a virtue and another should lack it: "He who ascribes the production of anything to the earth names indeed the location, but since the earth bestows location at least in part to all the things of earth, the location certainly by itself does not explain the production of a body."[37] Nor is it clear, on Steno's view, what properties matter itself might have that would enable us to account for the production of bodies. Thus does the bulk of the work fall to motion, and here Steno identifies three types: (i) the movement of the fluid that permeates all bodies, (ii) the movement of living beings (including those of human beings), and (iii) "the first and unknown cause of motion."[38] The last of these is of course the divine power that creates and continually shapes the things of the world anew, which Steno does not exclude from the full account of geomorphology, even as he makes explicit his desire to bracket it, other than in a brief excursus, in the *Prodromus*. The second of these types of motion reflects Steno's awareness of the value of ichnofossils in helping to tell the story of the earth's past. But it is not

35 Steno, *Prodromus*, p. 11: "[…] determinationem vero motuum naturalium […] mutari posse […] [a] motu animalium: & quae hoc modo ab homine fiunt eorum multa artificialia dicuntur."

36 See Kircher, *Mundus Subterraneus, quo universae denique naturae divitiae* (1665).

37 Steno, *Prodromus*, p. 15: "Qui productionem alicuius rei terrae adscribit, locum quidem nominat, sed cum rebus omnibus terrestribus locum saltem ex parte terra tribuat, solus vero locus productionem corporis non absoluat."

38 Steno, *Prodromus*, p. 11: "1. A motu fluidi omnia corpora permeantis: & quae hoc modo producuntur naturaliter produci dicimus. 2. A motu animalium: & quae hoc modo ab homine fiunt eorum multa artificialia dicuntur. 3. A prima, & incognita causa motus."

only ichnofossils that bespeak the past motions of living beings. So do fossils of all sorts, as well as the organic composition, both plant and animal, of geological strata.

What now about the motion of "fluids"? In fact there is a third principle of the study of solids within solids, in addition to the two identified by Gould in the previous section: for Steno, "if a body be produced according to the laws of nature, it is produced from a fluid."[39] Steno's ontology of fluids is broad here, and includes both the "subtle fluid" that permeates everything, as well as numerous subtypes of fluid involved in biological processes. What is of interest to us is the implicit principle within Steno's *Ex fluido omnia* doctrine, that it is characteristic of fluids (including "subtle" fluids such as "gas" or "chaos") to transmit information, while it is unique to solids to be able to preserve information. Thus the solids we observe today tell us a story of the earth's dynamic past, including the relative chronology of which solid bodies, in proximity to other solid bodies, were the more recently fluid. Thus the whole science of solids within solids, which is to say geology, is a historical science that relies on what is ultimately a highly speculative theoretical posit about the primordial state of physical nature. Steno summarizes this reliance as follows:

> [I]f at least all solids have grown from a fluid, if bodies mutually alike in all respects were also produced in the same way, if of two solids mutually in contact the first to harden was that which impresses its surface characteristics on the other surface, it will be easy, given the solid and its location, to make a definite statement about the place of its production. And this indeed is a general consideration of a *solid enclosed by a solid*.[40]

4 The Unknown

It will be helpful at this point to recall Steno's preoccupations at the time of the *Chaos* manuscript. It is often supposed, in a rather too facile manner, that the

39 Steno, *Prodromus*, p. 18: "Si corpus solidum secundum Naturae leges productum est, e fluido productum est."

40 Steno, *Prodromus*, p. 24: "Quod si itaque omne solidum e fluido saltem incrementa habuit, si corpora sibi inuicem omnino similia, simili etiam modo product sunt, si e duobus solidis sibi inuicem contiguis illud primo induruit quod alterius superficiei proprietates sua superficie representat, facile erit dato solido, & loco, in quo est, de loco productionis illius certum quid pronunciare. Et haec quidem generalis consideration est solidi intra solidum contenti."

great natural philosopher repudiated his interest in accounting for the natural world when he converted to Catholicism and, shortly after, descended into zealotry.[41] But what this account overlooks is that from the beginning Steno's interest in natural philosophy was rooted in what might be called mythopoetic speculation, and throughout his later scientific career he does not appear to have lost this religiously grounded motivation for his research.

In the *Chaos* Steno cites Jeremias Drexel's *Ioseph Aegypti prorex descriptus*, in which the author writes that "*Profana a sacris non excludenda*":[42] worldly matters are not to be separated from sacred ones. The study of geomorphology, for example, is not a departure from reflection on the divine, but rather an inflection of it. Years later, on the occasion of the dissection of a woman's body, Steno will offer a sort of corollary of the motto from the *Chaos*, that while the observable is beautiful, "By far the most beautiful is the unknown." As Troels Kardel remarks, "Emphasis on what is *not* known about a subject characterizes Steno's work in science, as also expressed in his adage."[43] Steno makes this observation late, on the occasion of a 1674 dissection in Copenhagen, but it would be a mistake to suppose that it is a sign of his impending abandonment of natural philosophy. We find a somewhat similar statement in the *Prodromus* as well, one that both grounds geological research in the broad history of philosophy, and also reveals what is philosophically and methodologically distinctive about that domain of natural philosophy that consists in probing into the unseen parts of the earth. To cite, again, the evocative 1671 English translation:

> Nor was it amiss, that Democritus made use of the similitude of a Pit, where a Man can hardly make a right estimate of the labour & time of drawing thence, but by having actually drawn up the things in it; for as much as the number and plenty of the latent Veins leave it very uncertain, what store there is of the subterraneous matter.[44]

41 For an exceptionally careful study of the complicated relationship between science and faith in Steno, see Sobiech, *Herz, Gott, Kreuz*. See also Bierbaum and Faller, *Niels Stensen: Anatom, Geologe, und Bischof*.

42 Steno, *Chaos*, col. 1, fol. 28^{r-v}. Cited in Miniati, *Nicholas Steno's Challenge for Truth*, p. 52. See also Drexel, *Joseph Aegypti prorex descriptus* (1640).

43 Kardel, "Prompters of Steno's Geological Principles," p. 159.

44 Steno, *Prodromus*, p. 2: "Nec male putei exemplo vtebatur Democritus, vbi hauriendi laborem, & tempus vix quisquam rite emensus fuerit, nisi exhauriendo; cum venarum latentium, & numerous, & amplitude materiae affluentis copiam dubiam relinquat."

What, exactly, is unknown is of course never a settled matter, and it is the task of natural philosophy to make more of what is unknown known. When Steno comments that the unknown is more beautiful than the known, the prescriptive force of his observation is inherently ambiguous: does he mean that what is unknown should be left alone, or does he mean that the fact that it is unknown gives us all the more reason to go after it? If Steno does abandon natural philosophy in favour of a stringent version of piety, this is not so much because he has taken a radical turn in his intellectual orientation, as commentators since Leibniz have supposed, but more likely because his understanding of natural philosophy had always been suspended between these two interpretations.

5 Conclusion

We may distinguish between the sort of unknowns that can be made known by cutting open a dead body, or by digging into the earth, on the one hand, and on the other the sort that remain perpetually unknown, by direct experience, as a result of the fact that they occurred in the irretrievable past. What we learn from the first sorts of inquiry helps to increase knowledge by means of induction, as when Steno observes in 1667 that nothing he has observed until now warrants the judgment that fossils are produced by the petrifying virtue of a place. But there is also the other species of unknown that Steno makes known, prior to his abandonment of natural philosophy, one that cannot be simply unearthed, but rather must be accessed by a different sort of reasoning than is ordinarily understood to be involved in empirical science in the narrowest sense. This sort of reasoning ranges not over newly unearthed objects in themselves, but rather over the past processes that produced these objects. These processes are strictly speaking inaccessible, but Steno's great contribution was to establish the form of reasoning that has the power to make them known nonetheless. In doing this, he also established geology as a fundamentally historical discipline, which it would remain through the most active period of its formation as a science, not least in the work of Lyell. Today its historical character is seldom acknowledged, or at least the special epistemological challenges that arise in sciences devoted principally to past processes are given short shrift by philosophers of science (and are generally not recognized as problems at all by practicing scientists). History, meanwhile, is generally treated as a non-science par excellence, and is seen as having nothing in common with the sort of inquiry into nature in which Steno and Lyell were engaged. And yet Steno's contribution to the epistemology of claims about past processes, and Lyell's

subsequent assimilation of geology to history, might yet show us a way forward for a future synthesis of the artificially separated investigations of the natural and human pasts.

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CHAPTER 8

Steno, Leibniz, and the History of the World

Daniel Garber

1 Introduction

Niels Stensen's main reputation as a natural philosopher was as an anatomist.[1] A careful observer, Steno did important early studies of the salivary glands and ducts, of the eye, of the nose, of the heart, the brain, and of many animals as well, including the chick, the hare, the calf, and, most famously, the shark. But Steno was also the author of a seminal work in what later came to be called geology, *De solido intra solidum naturaliter contento dissertationis prodromus*, *A preliminary dissertation on a solid naturally contained in a solid*, what is generally known as the *Prodromus*.

In this essay I would like to make some remarks about the geological project of the *Prodromus*. But I am particularly interested here in the influence that Steno's *Prodromus* had on another pioneer in the study of the Earth, Gottfried Wilhelm von Leibniz. Now, it is generally known that Leibniz knew Steno personally. The two met during Steno's time as Bishop of Titiopolis and the apostolic envoy of the Pope in Northern Europe, based at the Court of Hannover, between late 1677 and the summer of 1680. It is also generally known that the two had a number of serious conversations together. But it is generally thought that when Steno had taken up his religious calling, he completely abandoned his scientific interests, and that his conversations with Leibniz were exclusively about theological matters. But there is reason to think that this is not entirely true. There is, I claim, a manuscript attesting to the fact that during his time in Hannover, Steno met with Leibniz and discussed geological questions. I will further argue that this discussion, as well as Leibniz's reading of the *Prodromus* is reflected in the *Protogaea* some years later.

1 I use the following additional abbreviation: Steno: *Prodromus*: *De solido intra solidum naturaliter contento dissertationis prodromus* (1669). I provide the page number, followed by the page number in the English translation in KM, pp. 621–660.

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2 Steno and the *Prodromus*

Steno's interest in geological questions seems to date from travels that he made in Tuscany and other parts of Italy in 1667 and 1668. The small book was written in haste, before he left for Denmark, and finished by August 1668. It was available at the bookshops by the spring of 1669.[2]

The focus of the work was just what its title would indicate: the natural formation of solid bodies encased in other solid bodies. The kinds of things that Steno considers are "solids [...] which completely surround and contain crystals, selenites, marcasites, plants and their parts, animal bones and shells [...]."[3] The bulk of the treatise is concerned with showing how these solids formed, and how it is that through natural processes they became enclosed in other solids. Of particular interest to Steno here were the remains of animals. There had been a lively discussion well into the seventeenth century about whether or not such things as shell-like structures, plant-like traces, and apparent animal bones found in geological strata were the remains of actual living things, or whether they were "sports of nature."[4] Steno came down very decisively on the side of the claim that such things were the remains of plants and animals, and showed how it is that these remains could arise naturally through the motion of fluids and the settling of sediments.

An obvious problem, though, is that many of the apparent animal remains involved marine animals, particularly mollusk shells that were found far from current oceans, on the tops of mountains, and far inland. In the *Prodromus*, Steno talked about a "difficulty [that] troubled the Ancients, namely the way in which marine objects had been left in places far from the sea [...]."[5] In connection with this, then, Steno offered an account of the forces by which mountains and valleys currently found on the surface of the Earth arose. On this account, what are currently mountains were, at some time in the past, under water and thus appropriate places for marine life to exist.

Steno was not the first to speculate about how the irregularities on the Earth's surface arose. An important predecessor in this project was Descartes. Though much less detailed than Steno's account, Descartes' account of the

2 On this, see Scherz, *Biography of Nicolas Steno*, transl. in KM, pp. 203–233. This includes an annex containing supplementary material by T. Kardel. More generally on Steno as a geologist, see Scherz (ed.), *Dissertations on Steno as Geologist*.

3 Steno, *Prodromus*, p. 15, transl. p. 629.

4 See Smith, "Thinking from Traces," *infra*.

5 Steno, *Prodromus*, p. 7, transl. p. 625.

history of the Earth was much broader in scope than was Steno's. While Steno was interested largely in the history of the irregularities in the surface of the Earth, particularly in the history of mountains, Descartes goes back to the very origin of the Earth itself. On Descartes' view, the universe was originally an infinite collection of suns, what we see as stars, each of which had a vortex of fluid swirling around it. However, some of the smaller stars developed sun spots, which eventually came to cover the entire surface of the star. When this happened, the vortex was weakened, and the encrusted sun was captured by another neighboring vortex, and became a planet. This is how the Earth was formed.[6] Descartes' account of the formation of the irregularities on the surface of the Earth was rather elaborate. He had a very complicated story about how the surface of the encrusted star that became the Earth separated itself into a number of discrete layers through various purely physical processes.[7] In the end, however it happened according to Descartes' story, the Earth was left with a hard shell ("E" in fig. 8.1, top; see App. I), with an empty space F between it, a liquid layer D below F, and a solid layer C below the liquid.[8] Various mechanisms, Descartes argued, then caused cracks and fissures to appear in this crust E. The crust E eventually gave way in places, forming mountains and valleys. The liquid layer D then seeped out and formed the oceans (fig. 8.1, bottom; see App. I). In this way the mountains and valleys were caused by the lifting of plates from the once flat crust above the level at which they had been before the cataclysm that resulted in their formation.[9]

It should be noted here that Descartes' account was very, very sketchy, and not based on anything but the most general observations about the irregularity of the surface of the Earth. In particular, Descartes did not really worry about

6 Descartes, *Principia philosophiae*, IV, 2. The Latin text can be found in Descartes, *Oeuvres de Descartes*, vol. VIII/1; a contemporary French translation can be found in vol. IX/2. For a complete English translation, see Descartes, *Principles of Philosophy*. Since all the editions give Descartes' part and section numbers, I will not cite the different versions independently. It should be noted that Descartes was a bit cagey about saying that that is *actually* how the Earth was formed. Concerned about consistency with the biblical account in *Genesis*, he asserted that God created the Earth directly, but presented this story of the Earth as an encrusted star as an hypothesis, which shows how things could have arisen from prior causes, even though, Scripture tells us, they didn't. See *Principia* III, 45 and IV, 1. I think it is clear enough to us (as it was to his contemporaries) what he really believed.

7 Descartes, *Principia*, IV, 32–40.

8 Ibid., IV, 40.

9 Ibid., IV, 41–44.

how this story about the origin of the Earth might account for the apparent remains of marine life on mountain tops. Indeed, on this story, the tops of the mountains were the result of a solid crust that had been raised, and was never in contact with the watery layer D.

Now, Steno was much impressed by Descartes, who was a major influence on his thought. But it is not surprising that he did not seem to have followed Descartes' account of the origin of the Earth's irregular surface very closely.

In the *Prodromus*, at least, Steno seemed completely uninterested in the general question of the origin of the Earth: what interested him, though, were the geological processes that lead to the irregularity of the surface. Though they were subsidiary to the larger project of understanding the formation of solids within solids, they were still of great interest.

There are two principal discussions of the irregularity of the surface of the Earth in the *Prodromus*. The first is found after a general discussion of strata on Earth and their foundations. The section is labeled "Montium origo" in the margin.[10] In this section, Steno gave a general account of the formation of mountains. He isolated two different kinds of mountains. The first kind of mountain derived from the displacement of strata. Originally, Steno supposed, the different strata were parallel to one another, and one on top of another. Some mountains involved the displacement of these originally parallel strata. Mountains of this sort characteristically had the following sorts of properties:

1. Vast level areas on the summits of some mountains.
2. Many strata parallel to the horizon.
3. Various strata on the sides of mountains inclined at different angles to the horizontal.
4. Broken strata, on the opposite slopes of hills showing absolute agreement in form and material.
5. Exposed edges of strata.
6. Fragments of broken strata at the foot of the same range partly piled into hills and partly scattered over the adjoining terrain.
7. The clearest signs of subterranean fire [...].[11]

Steno, however, believed that there was a second kind of mountain whose origin was different:

10 Steno, *Prodromus*, pp. 32–34, transl. pp. 637–638.

11 Ibid., pp. 32–33, transl. p. 637.

> Mountains can also be formed in other ways, such as by the eruption of fires that belch forth ashes and stones together with sulfur and bitumen, and also by the violence of rains and torrents whereby stony strata, already split by changes in heat and cold, are tumbled headlong, while the Earthy strata, cracking under great heat, are broken down into various parts [...].[12]

From this Steno concluded that mountains did not exist at the beginning of things but arose later from geological processes. Furthermore, he claimed, just as mountains could arise, they could also be destroyed.[13]

Though he did not explicitly draw this conclusion, it follows from what Steno had written earlier in the *Prodromus* that even the tops of mountains of the first sort must have been under water at some point. This is because the formation of geological strata, according to Steno, must involve fluids that carry materials of some sort and deposit them in layers.[14]

This is the general account of the origin of mountains that Steno presented. At the end of the *Prodromus*, however, he returned to the question of the irregularity of the Earth's surface. But rather than discussing the general theory of how changes occur on Earth, Steno discussed in detail the surface irregularities specifically in Tuscany (Etruria).[15] Though he did not present any specific observations on which to base his account, Steno tells us that it is based on his experience as an observant traveler in that region, but, he claimed, applicable more generally to the surface of the world: "demonstrate[d] about Tuscany by induction from many places examined by me, so I confirm for the whole Earth from the descriptions of many places set down by various writers."[16] The account that Steno gave was not tied to any one particular location in Tuscany, but was a sort of generic account of the sequence of events that resulted in the final irregularities in the surface of Tuscany.

Steno began with the current state of the surface, illustrated in fig. 8.1, #20 (for all figures, see App. 1). He then worked back, step by step until he inferred the first step in the process, the state of the Earth at the beginning, before the irregularities arose (see fig. 8.1, #25). In this way he isolated six distinct stages in the development of the Tuscan surface, and, by implication,

12 Ibid., p. 33, transl. p. 637.

13 Ibid., pp. 33–34, transl. pp. 637–638.

14 See ibid., p. 27, transl. p. 634.

15 Ibid., pp. 67–76, transl. pp. 653–657.

16 Ibid., p. 69, transl. p. 654.

six distinct stages in the development of the surface of the Earth in general. The Latin he used here to talk about each individual stage was "facies," or "face," *facies Etruriae* or *terrae facies*. Having enumerated the six *facies* starting from the most recent, Steno then went through them beginning from the earliest, reviewing the connection between his naturalistic account and the biblical account of the Earth's development.

The earliest stage, illustrated in fig. 8.2, #25, shows a flat Earth, with successive strata all parallel and horizontal with respect to one another. But covering these strata is water. Steno wrote:

> That there was aqueous fluid, however, at a time when animals and plants had not yet appeared, and that the fluid covered everything, is proved conclusively by the strata of the higher mountains which are free from all heterogeneous material; the outline of these strata testifies to the presence of a fluid; their material bears witness to the absence of heterogeneous bodies; the similarity in materials and outlines of strata from different mountains that are widely separated proves indeed that the fluid was universal.[17]

In this first *terrae facies*, what would later become the "flat tops of the highest mountains were covered with water."[18] By the second stage, illustrated in fig. 8.2, #24, the water had disappeared from the surface, but "huge cavities" formed in underneath the top strata. The lack of support from below then caused FG to buckle and break, resulting in the third stage, illustrated in figure 23. This produces both mountains (the highest strata left on F and G) and valleys (the result of the broken planes). This, Steno claimed, was the period of the great Deluge. The next stage, stage four (fig. 8.2, #22) occurred when the resulting cavity filled with water from the Deluge which, in turn, brought sediment with it forming new strata. These seas, teeming with life, were much higher than seas are today, resulting in marine life well up into what are now mountains: "The production of hills from marine deposits testifies that the sea was higher than it is now, and this not only in Tuscany but also in very many places far enough from the sea."[19] Stage five (fig. 8.2, #21) involved new cavities forming under the planes, as the waters of the Deluge receded. These, in turn, resulted

17 Ibid.

18 Ibid., p. 68, transl. p. 654.

19 Ibid., p. 71, transl. p. 655.

in further breakage of the planes due to the weight of the water (fig. 8.2, #20). This resulted in the current state of Tuscany, and the world.

Let me make a couple of remarks about this general account of the origin of surface irregularities, the final topic Steno takes up in the *Prodromus*. First of all, in this account, which appears to be intended as a general account of the evolution of the Earth, he focused on only one of the two accounts of the formation of mountains he had mentioned earlier. In particular, he ignored the account in terms of "the eruption of fires" from inside the Earth, and concentrated on the origin of mountains and valleys from the displacement of strata alone. This is a bit strange. While there may not have been much in the way of volcanic activity in Tuscany, there certainly was notable volcanic activity elsewhere in Italy: it seems odd that he would have ignored Vesuvius, particularly since he visited Naples in November 1668.[20]

In the account that he did give of the formation of irregularities, what is striking is that mountains are not raised, as they are on the Cartesian account, but valleys are sunk: the tops of the highest mountains mark the original height of the original strata of the Earth in its earliest stage. Valleys form when strata internal cavities arise and higher strata are broken and sink. The presence of marine life and other traces of a watery past on the tops and sides of mountains derive from either the initial watery state of the Earth (fig. 8.2, #25) or from the much higher waters that once filled the cavities and valleys (fig. 8.2, #23 and 24).

3 Leibniz on the History of the World

For Steno, the question of the history of the world was subsidiary to the question of fossils and other hard bodies encased in other hard bodies. For Leibniz it was a central question, of interest in itself. It is, in fact, the central question at issue in the *Protogaea*, written in the early 1690s, but only published in 1749, long after Leibniz's death.[21] The *Protogaea* was intended, arguably, as the first

20 See KM, p. 236.

21 I am of course talking about the book of that title, and not the article by that title, published in the *Acta eruditorum* in January 1692. Quotations from the *Protogaea* come from Leibniz, *Protogaea*, ed. et trans C. Cohen and A. Wakefield. This edition gives the Latin and an English translation on facing pages. On the history of the composition of the *Protogaea*, see Garber, "De Ortu et Antiquissimis Fontibus Protogaeae Leibnitianae Dissertatio."

stage in Leibniz's grand history of the House of Hannover. The *Protogaea* begins as follows:

> [...] those who would trace our region back to its beginnings must also say something about the original appearance of the Earth, and about the nature of the soil and what it contains. For we occupy the highest region of lower Germany, one that is especially rich in metals. Moreover, our homeland is the source of remarkable speculations, and the rays of a public light emanating from here will also advance the exploration of other regions.[22]

In the *Protogaea*, Leibniz did, in fact, take up the question of the origin of fossils, and argued that they are the remains of animals and plants. Unlike what we saw in Steno's case, however, this was not the principal goal of the project.

The *Protogaea* was not the first time that Leibniz considered the origin of the world. One of his earliest published writings, the *Hypothesis physica nova* (1671), begins with a kind of cosmogony. The project of the *HPN* was to explain a wide variety of terrestrial phenomena in terms of an hypothesis about the structure of matter. But the structure of matter itself was explained in terms of the history of the Earth. Leibniz's procedure in the *HPN* was reminiscent of the creation story that Descartes told some years earlier in his *Principia philosophiae*. As noted earlier, Descartes' strategy was to derive the present state of the world from an initial creation and the laws of motion. Leibniz, too, started at the beginning with an assumed first state, a solar and a terrestrial globe (he ignored here the other planetary bodies, large and small), all infused with a universal ether. These two globes were set into motions of various sorts, resulting in these two bodies rotating each around its own axis, and revolving around each other, with light streaming from the sun to the Earth.[23] Leibniz argued that the pressure of the light against the surface of the Earth resulted in the production of tiny bubbles ("*bullae*") of matter. The project, then, was to explain the main phenomena of the world in terms of these tiny bubbles or corpuscles.

It is important to note that Leibniz's central interest in the *HPN* was not in explaining the geographical features of the Earth, but in grounding an empirical matter theory that could explain a wide variety of phenomena about the

22 Leibniz, *Protogaea*, pp. 2–3.

23 Leibniz, *Hypothesis physica nova*, §§1–10, A VI, ii, pp. 223–226.

behavior of bodies on the Earth: it is a treatise on matter theory presented in the form of a treatise on cosmogony and cosmology.

But in the *Protogaea*, Leibniz was quite centrally interested in the origin of the world. One inspiration for Leibniz's position here was quite clearly Descartes and the *Principia philosophiae*. In setting out the creation story at the beginning of the *Protogaea*, Leibniz noted, with apparent approval, what "certain priests of wisdom" proposed:

> Indeed, they suggest that there were once huge globes, like the fixed stars or our own sun, that either produced light or were jettisoned by a sun. Then their matter boiled and foamed until they were finally covered by the slags extruded during fusion. Similarly, as the ancients supposed, the sun would be veiled by increasing numbers of spots that would darken and eventually obscure it, something actually observed in our time, after the invention of the telescope. Still, the accretion of accumulated material extinguished the internal heat, with a cooled crust hardening all around. Thus was born an opaque star that would reflect external rays, just like the planets.[24]

I do not know what priests of wisdom Leibniz may have had in mind here, but the account corresponds reasonably well with what Descartes had proposed in the *Principia*: the Earth began its life as a star or sun, which became encrusted with sun spots.

Leibniz's account of the origin of the Earth followed Descartes pretty closely. On the other hand, his account of the origin of the irregularity of the surface was much closer to Steno. Leibniz wrote:

> [...] it is plausible that the crust, shrinking as it cooled, left behind great bubbles proportional to its size, that is, hollows under huge vaults, which enclosed air and moisture, as happens with metals and other things that become more porous through melting. Then the crust separated into certain sheets and, according to differences of material and heat, came together unevenly in clumps; indeed, it would have ruptured in places, with the broken fragments tumbling into sloping valleys, so that the harder parts, like columns, occupied the highest place. That is why there were mountains even then.[25]

24 Leibniz, *Protogaea*, pp. 4–5.

25 Ibid., pp. 8–11.

Similarly, he wrote:

> If, then, one is to take the direct path, nothing appears more sure than our belief that the vault of the Earth collapsed at the point where it was buttressed by weaker supports, that a huge mass then crashed into the sea which lay under it and had previously been enclosed, and that the mountain peaks were thereby exposed.[26]

Mountains, Leibniz claimed, were thus not raised, but, as Steno argued at the end of the *Prodromus*, exposed:

> I know that some suspect the Earth was swollen by the bursting forth of the wind, and that mountains rose up from the plain, and islands erupted out of the sea. […] But I find it less reasonable that the mighty Alps could have risen out of the already solid Earth through eruption. We know, however, that one discovers the remnants of the sea even in them. Since one or the other must have happened, it is much easier to believe that the waters sank of their own accord than that a huge part of the Earth was raised so high with incredible violence.[27]

This is certainly not from Descartes, who thought that the mountains arose from the displacement of strata as they rose above the prior surface of the Earth. Leibniz attributed the view to Thomas Burnet and his *Sacred Theory of the Earth*. One can, indeed, find such a view in Burnet.[28] But Leibniz also claimed that it was from Steno that he learned it as well. In the *Protogaea* he wrote:

> For a sound explanation of these things, we can turn to some thoughts from the clever writer [i.e., Thomas Burnet] who recently offered a *Sacred Theory of the Earth*, and who would construct mountains and valleys out of collapses, and to the works of several other scholars whose diligence he inspired. Not averse to such things, Steno had already thought this way before about collapses and sediments, after visiting a considerable part of Europe and noting the vestiges of broken domes in various places.[29]

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26 Ibid., pp. 16–17.

27 Ibid., pp. 56–59.

28 Ibid., pp. 18–19. Cf. Burnet, *The Theory of the Earth* (1697), I, 12, p. 105 ff.

29 Leibniz, *Protogaea*, pp. 18–19.

Leibniz continued with some recollections of discussions on the subject with Steno:

> I remember hearing him tell us about this often, and that he rejoiced in contributing, through natural arguments, and not without benefit for piety, to a belief in the sacred history and the universal flood.[30]

Now, Leibniz certainly learned from Steno by reading the *Prodromus*. In a letter to Christian Philipp on 11/21 March, 1681, Leibniz declared that while all of Steno's writings in physics were admirable, "that which most greatly merits our high estimation" was the *Prodromus*.[31] But the passage from the *Protogaea* that I quoted above suggests that Leibniz must also have discussed these geological questions directly with Steno, face to face.

In a way, it should not be surprising that Leibniz held such discussions with Steno. Steno arrived in Hannover to take up his position as apostolic envoy in early November, 1677, and stayed until the summer of 1680.[32] It is known that that he and Leibniz had a number of personal meetings throughout this period. A text Leibniz wrote, the *Conversatio cum Domino Episcopo Stenonio de libertate*, dated 27 November/7 December 1677, is apparently the record of such a direct exchange.[33] There are also notes on a manuscript copy of Leibniz's *Confessio philosophi* that have been established as being in the hand of Steno.[34] However, the general consensus is that their discussions were about religious and theological matters, not scientific.[35]

An argument in support of this claim comes from the fact that Steno seemed to have set aside his scientific interests at this stage of his life. In a letter to Leibniz in November 1677, shortly after he arrived in Hannover, Steno wrote about how he had turned away from his scientific interest, and to God. He indicates "how God, through anatomical discoveries, made me renounce any

30 Ibid.

31 A II, i, p. 814 and A I, iii, pp. 465–466. Leibniz doesn't seem to have bought his own copy of the *Prodromus* until June 1679 (see A I, ii, pp. 487–488). But I suspect that he had read it earlier than that.

32 See A II, i, 579n; A III, ii, pp. 226–227; A II, i, p. 568; and KM, p. 3. On Leibniz's relations with Steno during this period, see Lærke, *infra*.

33 A VI, iv, pp. 1375–1383, transl. in Leibniz, *Confessio philosophi*, pp. 112–130.

34 See Sleigh, "Introduction," in Leibniz, *Confessio philosophi*, pp. xxi–xxii.

35 See Scherz, "Gespräche Zwischen Leibniz und Stensen," pp. 81–104; Waschkies, "Leibniz' geologische Forschung im Harz," pp. 197–198. Lærke, *infra*, focuses on their theological exchanges.

philosophical presumptions, and reduced me, little by little, to receive the love of Christian humility."[36] A few months later, in early February 1678, in a letter to Melchisédech Thévenot, Steno repeated that he had lost interest in scientific matters: "Alas, Sir, all of the curiosities of the world are only vanities […]."[37] When Leibniz reported Steno's arrival to Hermann Conring in January, 1678, he noted: "The gentleman is moderate, and, as I judge, good. In anatomical matters and all natural philosophy he is exceptionally well versed, as you know. I am sorry that he is now separated himself from this kind of studies."[38] In another letter to Hermann Conring, 19/29 March 1678, Leibniz wrote that he was sorry that Steno had given up his physiological studies, "since in theological studies, he has many equals, but in physiological studies, few."[39] In the *Essais de Théodicée*, his judgment was blunter still: "He [Steno] was a great anatomist, and well versed in the knowledge of nature, but he unfortunately abandoned his inquiries into it, and from being a great natural philosopher, he became a mediocre theologian."[40] All of this might reasonably be taken to mean that when in Hannover, Steno had completely set aside his scientific interests. If so, it would seem rather unlikely that he and Leibniz would have had a conversation about his geology.

But perhaps this conclusion is too hasty. There is no question that Steno had set aside his scientific activities, and focused on his life in the Church. But even so, it is not impossible that from time to time, he could be coaxed into a discussion or two about some of his earlier interests. This, after all, is what Leibniz himself suggested in the *Protogaea* when he noted that he, Leibniz, "remember[s] hearing him [Steno] tell us […] often" about how mountains and valleys arose. There is now some direct evidence to substantiate Leibniz's recollections. There is a remarkable manuscript that has gone largely unnoticed that, I argue, attests to such a conversation. (See the appendix for a facsimile of the manuscript, a transcription, and a translation).

Manuscript LH XXXVII, VII Bl. 20[41] in the *Leibniz-Archiv* is explicitly dated "January 1678" by Leibniz himself, about two months after Steno's arrival in

36 A II, i, p. 578.

37 EP I, p. 372.

38 A II, i, p. 577.

39 A II, i, p. 599.

40 Leibniz, *Essais de théodicée* (1710), § 100, VI, p. 158.

41 This is the now-standard catalogue number given in Bodemann, *Die Leibniz-Handschriften*. The entry for the ms. is found on p. 330. A scan of the ms. is now available online at http://pom.bbaw.de/DigiGal/Gallery?image=LH037%2C07_020%2Bra-02376.jpg&size

Hannover. The manuscript is clearly connected to the geology of Steno's *Prodromus*. The manuscript begins with two diagrams that look like they come directly from the final section of the *Prodromus*, the section where Steno discussed the origin of the irregularities in the surface of the Earth in Tuscany. The text then opens with the words: "Facies terrae," "The faces of the Earth." This is exactly the term Steno uses repeatedly to refer to the stages in the evolution of the surface of the Earth. There are many details in the text of the manuscript that follows that correspond clearly to the account of the origin of irregularities on the surface of the Earth that Steno gave in the last section of the *Prodromus*, where he discussed the evolution of the surface of Tuscany. The text of the manuscript discusses the irregularities on the surface of the Earth, the formation of mountains and valleys, the earlier state of the oceans, the presence of salt and shells on the high mountains and hills, all topics discussed in the *Prodromus*.

So far all of this is consistent with the view that the manuscript constitutes Leibniz's reading notes on the *Prodromus*. But there are other details that lead me to the conclusion that this manuscript is the record of a direct conversation Leibniz had with Steno in January 1678, a time when they were both together in Hannover.

The first diagram at the top of the manuscript closely resembles fig. 8.2, #20 at the end of the *Prodromus*, and the second closely resembles fig. 8.2, #21. But there are some interesting differences. The letters in the first diagram are different than those in the *Prodromus*, and the second figure has no letters at all. That suggests to me that the figures in the manuscript were taken not from the text of the *Prodromus*, but perhaps from a sketch that Steno may have made on the spot. Furthermore, the first figure in the manuscript contains an important detail, labeled 'c', that the corresponding figure in the *Prodromus* lacks. This leads us to a discussion in the manuscript that can be linked with Steno, but which is not found in the *Prodromus* or, for that matter, in any of his other published texts.[42]

=mid and http://pom.bbaw.de/DigiGal/Gallery?image=LH037%2C07_020%2Bva-02378.jpg&size=mid for the *recto* and *verso* respectively. The earliest reference to this manuscript I know of in the literature is in Roger, "Leibniz et la théorie de la terre," p. 137. I later refer to it in Garber, "De Ortu et Antiquissimis Fontibus Protogaeae Leibnitianae Dissertatio," p. 172. I know of no other discussions of it in print. Neither Roger nor myself in the earlier essay recognized the full significance of the manuscript.

42 It is interesting to note, though, that there is a missing geological ms. that may contain some of this material. See Garboe, "Niels Stensen's (Nicolaus Steno's) Lost Geological Manuscript."

In the first paragraph of the manuscript there is a discussion of salt deposits in the Tirol region of Austria that does not appear in the *Prodromus*. The existence of these deposits is advanced as an argument for why we should believe that even the highest mountains were once under the oceans. This is the little pocket 'c'. Kardel and Maquet cite a letter written by Anna de' Medici on June 16, 1669, where she notes the pleasure that she took in "the very substantial discourse that he [i.e. Steno] made after visiting the salt works of Hall …"[43] It is plausible to suppose that the "salt works of Hall," a town in the Tirol famous for its salt pits, is what Leibniz was referring to in the first paragraph of the manuscript. It is also plausible to suppose that it was Steno who told Leibniz about them, just as he had told Anna de' Medici about them almost ten years earlier.

A second discussion in the manuscript attributable to Steno that does not appear in the *Prodromus* concerns the first animals on Earth. In the manuscript, Leibniz writes: "He thinks that water necessarily covered the entire Earth at one time, and therefore that all animals then had been at least minimally aquatic." Now, in the *Prodromus* Steno certainly holds that at one time, water covered the entire Earth. But he did not argue there (or in any other published source that I know of) that all animals then had to be aquatic. In a later manuscript, however, dated by the Academy edition at 1686–1687, not many years after this manuscript, Leibniz attributed precisely this view to Steno: "It is the opinion of Steno, that the globe of the Earth was once completely covered with water […] and that once animals for the most part were aquatic, and little by little became amphibious."[44] An obvious suggestion is that Leibniz got this idea from conversation with Steno, and that the manuscript we have been discussing is a record of that conversation.

And finally, there are elements of the manuscript from January 1678 that strongly suggest the kind of exchange of views characteristic of a face-to-face conversation, rather than just notes on a text that cannot talk back. Some of the personal comments Leibniz seems to make in his own person could well appear in notes on a printed text. For example, at the end of the first paragraph, there is a parenthetical remark ("I must examine …") set off by '+' signs, in the way in which Leibniz would often interject his own comments in notes on someone else's text. There is a later parenthetical remark ("I would prefer …") which is comparable, though it lacks the '+' sign that normally indicates that Leibniz is speaking in his own voice. The final paragraph, however, looks very much like a direct dialogue between Leibniz and whoever is advancing the view under dis-

43 See E I, 17. Cf. KM, p. 243.

44 A VI, iv, pp. 2466–2467.

cussion. The paragraph begins by noting that "he thinks that necessarily water at one time covered the entire Earth [...]." Next follows the question of whether that would mean that all animals then were aquatic. What follows after that is an interesting back and forth. It might be said, then, that animals were not purely aquatic, but amphibious, spending part of their lives in water and part on land, and that terrestrial animals derive from amphibians. Or, it might be suggested that there were higher mountains than we now have that later collapsed, presumably giving purely terrestrial animals a place where they could exist outside of water. It is further proposed that perhaps there wasn't enough water to cover all of the Earth. All of this suggests a face-to-face discussion, though one might still imagine this to be notes on a text, with either Leibniz's or the author's objections and replies. But then there is the last sentence:

> For the water which does not now suffice [to cover A and B] corresponds to the water *I was talking about*, which had indeed diminished, and then also a great part of which had been drained and absorbed in the deep cavities of the earth opened up by those catastrophes.

This looks like a face-to-face exchange, where Leibniz is reminding Steno of a view that he had brought up earlier in the conversation. Since I think it is clear that the positions under discussion in the manuscript as a whole are those of Steno, it is reasonable to suppose that the dialogue is between Leibniz and Steno, and that these are Leibniz's notes of that dialogue.

If this manuscript is indeed the record of a conversation between Leibniz and Steno, then there may be further hitherto unnoticed influences of Steno on Leibniz's *Protogaea*. In the manuscript Leibniz wrote:

> Near Amsterdam, Muiden, and Naerden, beneath the earth shells are found in several veins [*brachiis*], and below that stumps or trees, all facing the same directions, as if they had been enveloped and covered up by a common catastrophe. We must add the account in Mersenne about the well in Amsterdam.

It is very interesting, then, that in *Protogaea*, chapter XVII, Leibniz discussed the phenomena of "whole and broken trees hidden from us under clay. And it is remarkable that most of them lie in the same position, with the roots pointed between north and west, and the tips pointed between east and south."[45] This,

45 Leibniz, *Protogaea*, pp. 138–139.

he argued was probably the result of a single catastrophic event: "[…] learned men believe that in a time before all reported history, the boiling ocean, raging from the northeastern and northwestern winds that still attack these coasts today, burst onto the land with great force."[46] Then, interestingly enough, in the very next chapter of the *Protogaea* we find an account of what was discovered when a well was dug in Amsterdam. "When a well in Amsterdam was dug to a depth of two hundred and thirty-two feet," Leibniz reported that they found a series of discrete layers, including repeated layers of peat, clay, earth, and shells.[47] This he attributed to successive cataclysms in the region:

> Repeated floods and catastrophes have thrown all the layers of clay and sand upon this floor, while the deposits of earth arose during the intervening periods. The sea, driven back, retreated for a time. But ultimately, insisting on its right, the sea once again burst the dams, flooding the lands and flattening the forests, whose ruins are now revealed by the diggers.[48]

Now, in chapter XLVII of the *Protogaea*, Leibniz talked not about Amsterdam, Muiden, and Naerden, as in the manuscript, but about other close-by regions in Germany, the Netherlands, and Belgium, including Lüneburg, Bruges, Frisia, and the province of Groningen. Furthermore the only observer mentioned explicitly in this connection is not Steno, but Bootius of Bruges. Moreover, in the discussion of the well in Amsterdam in chapter XLVIII, Mersenne was not mentioned, nor was any other source. But the correspondence between the manuscript and these chapters of the *Protogaea* seems too close to be coincidental. It is at least a good conjecture that Leibniz may have first learned about these phenomena from a conversation with the new Bishop of Titiopolis.

4 Conclusion

In Leibniz's account of the origin of the Earth, then, we have an interesting combination of features: we have Descartes' fantasy of the radical origin of the Earth from an encrusted sun, together with Steno's much more empirically solid account of the irregularities of the surface, arising from the sinking of the planes to form valleys, leaving mountains behind. But more interesting still,

46 Ibid.

47 Ibid.

48 Leibniz, *Protogaea*, pp. 140–141.

we have reason to believe that Leibniz came to this view not only through reading Steno's remarkable *Prodromus*, but through direct conversation with its author.[49]

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49 Would like to thank the participants in the conference, "Steno and the Philosophers" in Paris in February, 2015 and in the conference, "Leibniz and the Sciences" in Leipzig in November, 2016 for lively discussions that considerably improved this paper. I would especially like to thank Mogens Lærke for his careful editing of the essay. Though I had a sense that there was something interesting in the Leibniz manuscript discussed in the text and presented in the appendix, it was also significantly beyond my paleographical skills to transcribe it accurately. I am deeply indebted to Anne-Lise Rey, who did the initial transcription, and to Eberhard Knobloch, who reviewed and corrected both the transcription and the translation. I would also like to acknowledge with gratitude the kind help from Dimitri Bayuk, Andrea Costa, Olga Federova, Vana Grigoropoulou, Enrico Pasini, and Martine Pécharman, who commented on both the transcription and on my translation.

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Appendix 1

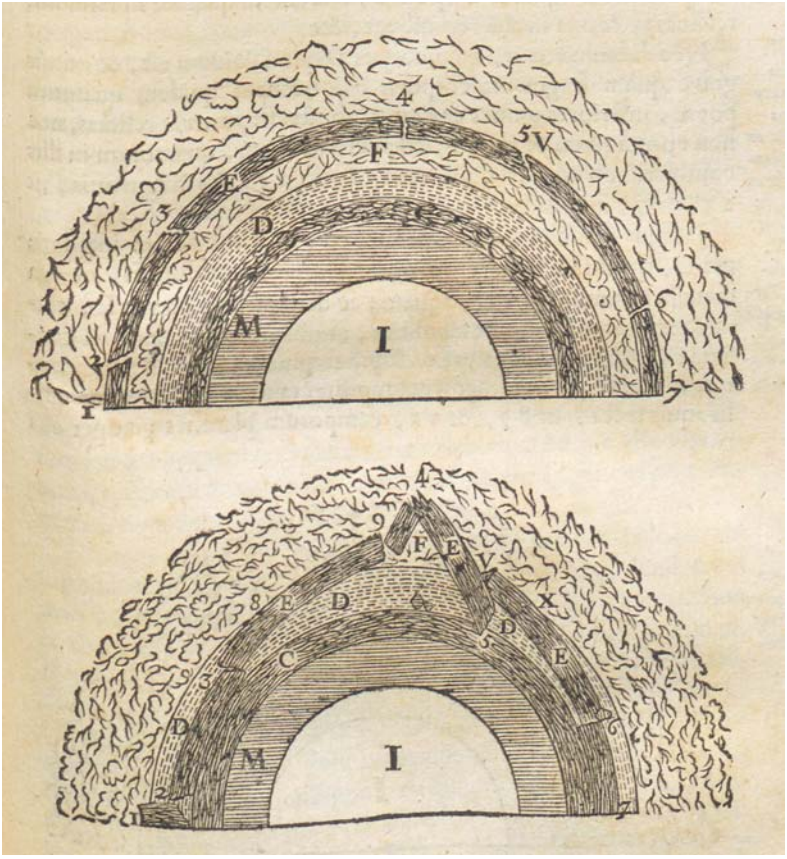


FIGURE 8.1 *Descartes,* Principia philosophiae *IV*

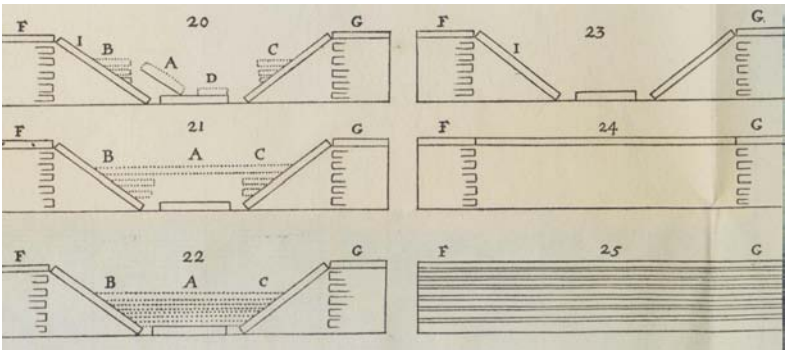


FIGURE 8.2 *Steno,* Prodromus (*1669*)

Appendix 11

LEIBNIZ, LH XXXVII, VII Bl. 20: TRANSCRIPTION

20r Januar 1678

Facies terrae. Tria eius velut plana, juga summa ut Alpium. Medii colles; et infima plana versus mare. Media inprimis conchyliis plena passim. Nimirum ex summis abluta mediis invecta. Si dicatur magno tempore ad sedimenta opus fuisse, respondet eleganter ita esse, si sedimenta hodierno modo facta dicantur, ubi subinde torrentes aliquid auferentes a terra novos paulatim formant colliculos; sed hoc modo multis opus foret seculorum millibus. Et intervallum inter strata, quippe tam parva debet esse exiguum. Sed strata illa terrarum et conchyliorum quae reperiuntur in montibus deprehenduntur esse maxima altitudinis, multorum passuum, adeoque aliquando una generali ruina facta, vel tempore, quo crebriores fiebant ruinae et mutationes magnae.

Aquam maris in summis montium fuisse egregio exemplo patet ex Tirolensibus salinis, quae sunt in summo alpium jugo vide figuram lit. C ubi caverna, in qua argilla sale mixta: haec argilla exposita aeri rumpitur in frusta et fissurae salem praebent. Ipsa argilla est tenacissima, ita, ut sine fornicibus vel sustentaculis possit excavari in cameras, id fit ab inferiori parte. Inde immittitur in illam concamerationem aqua dulcis, quae ubi salem imbibit, cujus signum habent incolae, emittitur per alios canales et excoquitur; porro extracto sale sponte cadit pars concamerationis, et altius excavatur concameratio; donec ad summum nempe rupem perveniatur. Notant autem in locis semel extractis non novum unquam succrevisse salem. Videtur ille generatus, cum in ruinis illis augentibus aquae marinae portio probe terrae mixta atque inclusa fuisset obruta, quae terra exiccata in argillam, sale intus relicto ac deprehenso. Hinc ergo

LEIBNIZ, LH XXXVII, VII Bl. 20: Translation

January, 1678

The faces of the earth. Three of them are like plains, the highest summits as in the Alps, the middle like hills, and the lowest like plains facing the sea. The middle ones are especially full of shells everywhere. They were certainly washed off the summit and deposited in the middle regions. If it is said that more time was needed for the sediments, he elegantly replies that that is so, if the sediments were said to be formed in the way in which they are now, where constantly rushing torrents bearing something from the ground form new little hills little by little. But [for it to happen] in this way requires many thousands of centuries. And there would have to be an interval between strata, however small. But those strata of different soils and of the shells found there on mountains are found to be at the greatest height, at thousands of feet, and therefore were made at some time in a general catastrophe, or at a time when there were frequent catastrophes and great changes.

It is evident that the water of the sea was on the highest mountains because of the excellent example of the Tirolean salt deposits, which are on the summits of the highest Alps (see figure, letter C), where there is a grotto in which there is clay mixed with salt. This clay, when exposed to the air, is broken up into small pieces, and the fissures yield up salt. The clay itself is very firm so it is taken from the lowest portions [of the caves], and thus it can be excavated in chambers that need neither vaults nor supports. And then fresh water is sent into those vaults, which absorbs the salt there. When the inhabitants have an indication [that the salt has been absorbed], [the water] is then emitted through other conduits and dried out. Then, when the salt has been extracted, a part of the vaulting spontaneously falls and the vaulting is excavated higher. And so on until the top of the cliff is reached. Moreover, they note that in places where [the salt] was once extracted, new salt has never grown back. It [i.e. the salt] seems to have been produced when in those spreading catastrophes a portion of sea water thoroughly mixed and enclosed in earth had been buried. The earth, the salt remaining and having been trapped in it, dried into clay. Therefore, from this it is inferred that the sea water had been on the mountain tops.[50]

50 On the Tirolean salt deposits, see KM, p. 243, and EP I, p. 17.

colligitur aquam maris fuisse in summis montibus (+ examinandum, an sal gemmae crescat in Polonia ut quidam aiunt, ex loco unde excisum est +).

Porro inspiciatur figura ecce A et B summa montium cacumina circiter in eodem plano, ut appareat illic fuisse planum, aqua autem mediam partem, quippe non aeque duram eluit, aut effregit vel intra excavavit quae postea per terrae motum concidit. D. des couches de pierre, rupeae, eiusdem naturae cum A. ita ab altera parte E. Etsi autem A et B in eodem plano non tamen D et E eiusdem inclinationis semper. Rursus collis F et G eiusdem circiter horizontis eodem modo novum scilicet planum ab aqua factum, postea denuo elutum, collium huiusmodi fundi crassities ut N, stratis arenae, conchyliorum, item, subinde conchyliorum, ut arenis mixtorum. Et si observes respondens horizontaliter M ipsi L, et O ipsi N, reperientur ejusdem naturae strata, ideo media cavitas abrupta sive eluta modo. FHP circiter eiusdem naturae. In Lombardia fluvius ingens sub terra instar Padi alicubi cum aperiunt in latere foramen aqua

(+ I must examine whether "sal gemmae" grows in Poland from the places where it is gathered, as they say it does. +)

Now, let us inspect the highest summits of the mountains (see A and B in the figure) that are approximately on the same plane, so that it appears that there had been a plane there, and water washed away the middle part, which wasn't equally hard, or broke open or hollowed out something that later fell because of an earthquake. D. [are the] rock strata,[51] rocky, of the same nature as A. And similarly, on the other side, E. Moreover, even if A and B are on the same plane, D and E are not on the same incline. On the other hand, hill F and hill G, however, are on about the same horizontal [plane], namely a new plane produced by water that had later washed away once again. The bulk of hills of this kind are composed of [strata] like N, strewn with sand, shells, and the like, and then again shells, mixed with sand. And if you observe the corresponding horizontal [strata], M [corresponding to] L, and O to N, one will find strata of the same nature, and therefore an empty space in the middle only cut through or only washed away. FHP is of about the same nature.

In Lombardy, there is a remarkable stream below the earth, like the Po. When in some places it comes upon a hidden hole, water springs out like the jet of

51 "*couches de pierre*," in French in an otherwise Latin text. In normal seventeenth-century French, "*couche*" is used for a bed, particularly the marital bed, or for the confinement a pregnant woman undergoes. From the mid-eighteenth century on, though, "*couche*" is a common technical term in geological writings; it is, for example, very prominent in Buffon's writings. But it can be found in the geological sense in the late seventeenth century as well, directly linked to Steno. In Paolo Boccone's *Recherches et observations naturelles* (1674), he writes: "From this whole discourse, gentlemen, we can conclude, it seems to me, that even though the productions of the sea are now found quite far from the sea, it doesn't follow however that it [i.e., the sea] had never been there, since as Mr Steno says, if in a stratum [*couche*] of earth one finds rocks, sea salt, the remains of marine animals, bones, spines, teeth, the debris of ships, and a substance similar to that on the bottom of the sea, it is very certain evidence that at another time, the sea had covered these places [...]" (p. 328; see also p. 217, 219, 239, 249, 325). Though they do not seem ever to have met, Boccone exchanged a number of letters with Steno and discussed some scientific questions with him (see KM, pp. 278–279). The letters can be found in EP, letters 57, 64, and 89. Leibniz seems to have known this work of Boccone's. His notes, which the Academy Edition tentatively dates from February to September 1676, are published in A VIII, ii, pp. 593–605; the term "*couche*" appears on p. 605.

exilit instar fontis salientis. Auditur eius murmur posset aliquando per ruinam seu terrae motum detegi.

20v Prope Amstelodamum, Muyden et Naerden aliquot sub terra brachiis reperiuntur conchylia, et inferius adhuc ligna seu arbores, omnes in unam eandemque partem versae, ut pateat ruina communi involutas et obrutas. Addatur relatio apud Mersennum de puteo Amstelodamensi.

Fluida magis magisque consumuntur, consideremus ex quantulo semine quanta planta, utique non nisi per fluidum alita et nutrita (dici potest terram etiam redditam fluidam ad eam nutriendam) omnis generatio ex fluido facit fluidum; mavis vero non ex solido fluidum statum sed aliud solidum nunquam enim ita res destruuntur, igne vel aliter quin multo plus remaneat quam fuit materiae solidae in semine, ante generationem. Unde videtur multo plus olim aquae fuisse quam nunc est. (Ego malim esse circulum, et fere tantundem rursus fluidi produci quia a tanto tempore historiae non docent pluviorum et aquarum quantitatem notabiliter diminutam.)

Putat aliquando necessario aquam texisse totam terram, et ideo tunc omnia animalia minimum aquatilia fuisse. Nullum ergo tunc genus humanum. Responderi potest tunc animalia quae nunc mere terrestria sunt, fuisse saltem amphibia, paulatim vitam in aquis dedicidisse, uti foetus in utero quibusdam

a fountain.[52] Its noise is heard, and [such subterranean streams] sometimes could be detected through a cave-in or an earth quake.

Near Amsterdam, Muiden, and Naerden, beneath the earth shells are found in several veins [*brachiis*], and below that stumps or trees, all facing the same directions, as if they had been enveloped and covered up by a common catastrophe.[53] We must add the account in Mersenne about the well in Amsterdam.[54]

Fluids more and more get used up. We might consider how a great plant [arises] from a very tiny seed, fed and nourished only through fluids. (It can be said that even earth is rendered fluid to nourish it). All generation makes fluid from fluid. Or rather, a fluid state doesn't arise from a solid, but on the contrary another solid [arises from a solid]. For things are never destroyed through fire or some other way [of destroying a plant] without it happening that much more solid matter remains than there was in the seed before it sprouted. Whence it seems that there was once much more water than there is now. (I would prefer that there be a circle, and about as much fluid was produced [as was used up], since from quite a period of history we have not been taught that there was a lesser quantity of rain or waters).[55]

He thinks that water necessarily covered the entire earth at one time,[56] and therefore that all animals then had been at least minimally aquatic.[57] Therefore, there were no human beings then. It could be responded that animals that are now only terrestrial had then been at least amphibious, and had little by

52 On Steno's visit to Lombardy, see Corra and Farrari, "Itinerari di Stenone nelle Prealpi Tridentine e Lombarde," pp. 175–201. For the documents that this article draws on, see EP I, pp. 238–240 and pp. 241–246. There is no mention here of underground streams.

53 Cf. Leibniz, *Protogaea*, XLVII.

54 Cf. Leibniz, *Protogaea*, XLVIII. I have not been able to identify the reference to Mersenne here.

55 The parenthetical comment may be Leibniz's. On the problem of where the water came from and where it went after the Great Deluge, see Leibniz, *Protogaea*, VI.

56 Steno, *Prodromus*, p. 68/p. 654.

57 Cf. A VI, iv, pp. 2466–2467, a text from 1686–1687 (?), where Leibniz attributes this view to Steno: "Sententiae Stenonis, quod globus terrae aliquando totus aquis tectus fuit, ac de stratis et sedimentis; et quod animalia olim pleraque fuerint aquatica, et paulatim facta sint amphibia." The view is not found in the *Prodromus*, but is discussed in the Leibniz, *Protogaea*, VI.

instructus est, quae in nato, et respiratione opus habente mutantur et clauduntur. Potest etiam dici animalia terrestria fuisse ex amphibiis ut tritonibus et sirenibus nata. Item responderi potest ultra A. B. in figura potuisse esse adhuc altiores rupes extantes, quae postea concidere. Objici potest, unde tantum aquae, nam aqua quae nunc non sufficit respondet tum quod dixi aquam fuisse valde diminutam; tum etiam aquarum magnam partem forte fuisse in profundis terrae cavitatibus ruina illa detectis haustam et absorptam.

little unlearned their life in the water, like a fetus in the womb in a certain way is equipped with some things that are changed and closed in the fetus once born and needing to breathe. It can also be said that terrestrial animals had been born from amphibians like tritons and sirens. It could also be responded, furthermore (see A and B in the figure) that there could have been cliffs higher still which afterwards collapsed. It could be objected, whence so much water? For the water which does not now suffice [to cover A and B] corresponds to the water I was talking about, which had indeed diminished, and then also a great part of which had been drained and absorbed in the deep cavities of the earth opened up by those catastrophes.[58]

58 See Leibniz, *Protogaea*, XXXIV, p. 98/p. 99.

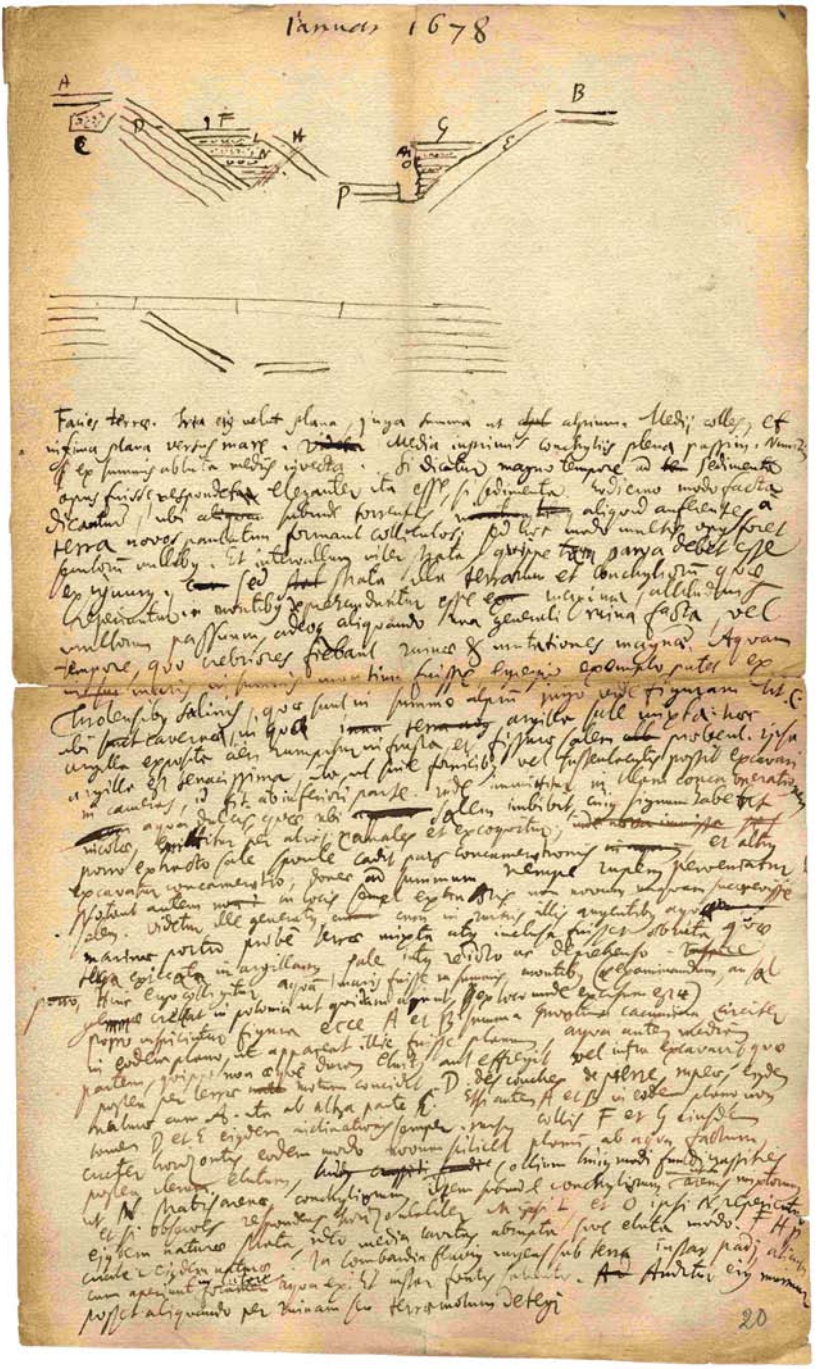
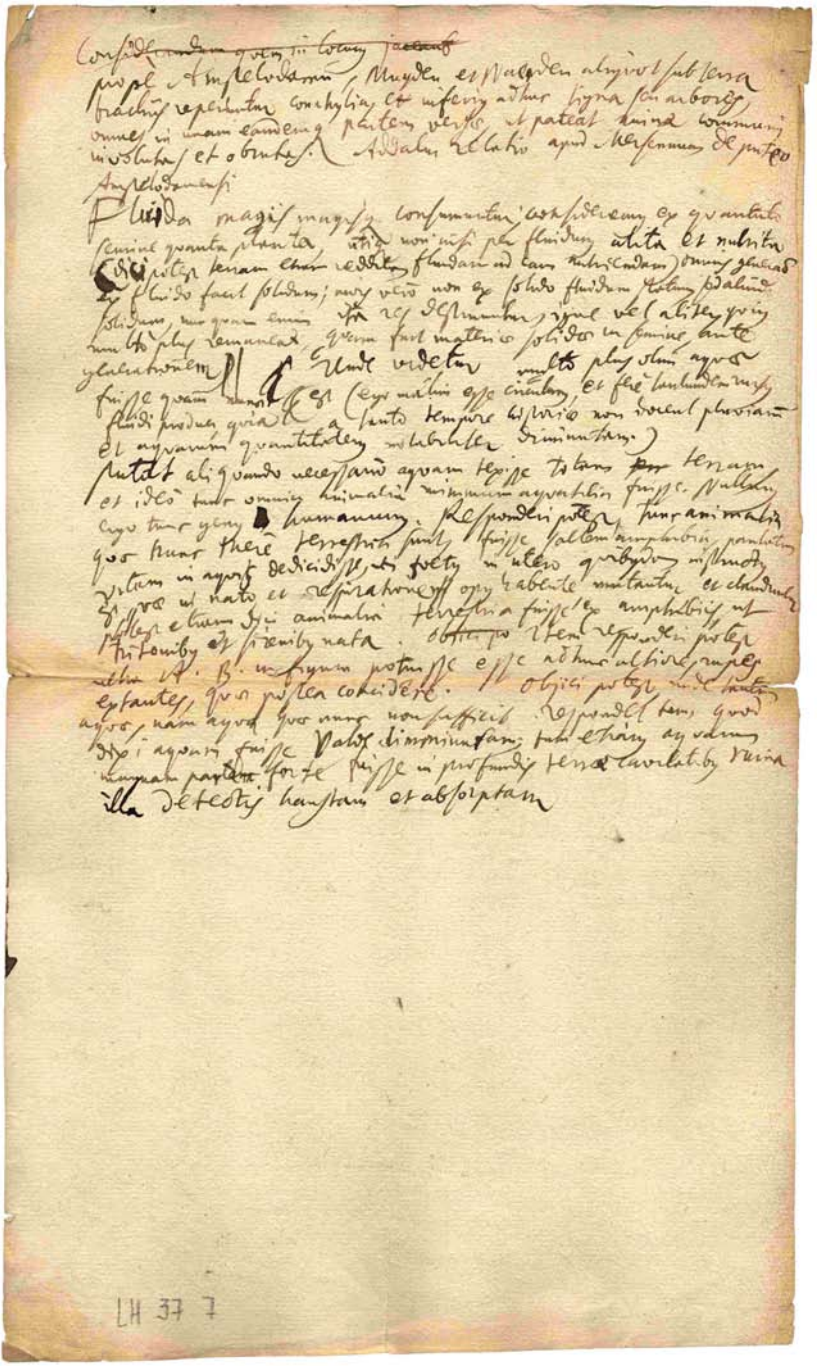


FIGURE 8.3 *Facsimile of Leibniz's manuscript* LH XXXVII, VII Bl. 20



PART 4

Steno at the Medici Court

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CHAPTER 9

Steno's *Historia*: Methods and Practices at the Court of Ferdinando II

Jakob Bek-Thomsen

1 Introduction

With an introduction befit for a duke, Nicolaus Steno described the mystery and difficulty of natural philosophy as elegantly as he could in the opening of his first work on the natural philosophy of the Earth:[1]

> Travelers into unknown realms frequently find, as they hasten on over rough mountain paths toward a summit city that it seems very near to them when first they decry it, whereas manifold turnings may wear even their hope to weariness. For they behold only the nearest peaks, while the things which are hidden from them by the interposition of those same peaks, whether heights of hills, or depths of valleys, or levels of plains, far and away surpass their guesses; since by flattering themselves they measure the intervening distances by their desire.[2]

De solido intra solidum naturaliter contento Dissertationis Prodromus appeared in April 1669. It was dedicated to the Grand Duke of Tuscany, Ferdinando II, and had been read and censored by Steno's good friends, the physician Francesco Redi and the mathematician Vincenzo Viviani, both of whom were also members of the Tuscan Court. Steno was not even present in Florence when the *Prodromus* was published. He had been summoned to the Danish court by King Frederik III and was *en route* through Europe. Because of this, Steno had been forced to hasten his work on physics and geography, and produced a "prodromus" rather than his intended full study of the Earth. The traveler's analogy introducing *Prodromus* is in this perspective both an image of the difficult

1 I employ the following abbreviation for archival material: MS Gal # = *Manuscritti Galileiani*, Florence: Biblioteca Nazionale Centrale di Firenze.

2 Steno, *De solido intra solidum naturaliter content dissertationis prodromus* (1669). The first edition of *De solido* is also found in OP II, pp. 183–224 and as a printers manuscript in MS Gal 291, f. 1^{r}–26^{v}. I will mainly refer to the version in OP; here OP II, p. 183.

 | DOI: 10.1163/9789004360655_011

and unpredictable ways of natural philosophy and an excuse for not meeting his promised deadline. And Steno was indeed mindful of his obligations and promises to Ferdinando II and his brother Leopoldo de Medici.

Upon his arrival in Tuscany in the spring of 1666, Steno was welcomed with open arms by the Medici Court. This was no less thanks to his Parisian patron Melchisédec Thévenot who had recommended Steno to his Italian correspondents.[3] In return, Steno became enamored with Tuscany, its people and its religion, and it became his center of departure during the following decade.

In the following, I wish to demonstrate the influence of the Medici Court and the Cimento group on Steno's work and his conception of knowledge production. I will do this by making two claims: 1) The *Accademia del Cimento* was not an academy but a project in a line of Medici founded projects; 2) Steno's geological work in *Canis Cachariae* and *Prodromus* was methodologically inspired by the philosophical milieu at the Medici Court as exemplified by the *Cimento* publication *Saggi di naturali esperienze*. The main purpose is to demonstrate the importance of scientific and philosophical collaboration for Steno's ideas rather than a narrow analysis of his uniqueness.

2 An Academy of Experiments

In his seminal work on the *Académie Royale des Sciences*, Roger Hahn maintained that scientific societies of the 1660s displayed three characteristic marks, all concerned with the promotion of science and representative of an organizational revolution: 1) each society had a communal instinct to share information both internally and externally; 2) each society had an organizer, an "intelligencer" and its "*Saggi, Mémoires*, or *Transactions*;" finally 3) the members regarded experimentation as their highest calling.[4]

Hahn's analysis might be valid for many early modern academies but it is not entirely fitting to the Cimento. On the surface, it is also obvious to see how the *Cimento* could be regarded as one of the most important among the early academies, since the *Saggi* displayed all those characteristics of an organizational corporation. Yet the *Accademia del Cimento* was atypical in comparison with the *Royal Society* and the *Académie Royale des Sciences* for a number of rea-

3 As documented in Steno's letter to Thévenot, undated, 1666, EP I, n° 21, p. 188. The letter is included in Steno's *Elementorum myologiae specimen* (see OP II, pp. 95–106).

4 Hahn, *The Anatomy of a Scientific Revolution*, p. 3.

sons: It never received an official charter and never officially ceased to exist; it was only active for a decade (1657–1667) and had a very limited group of practicing members; it never organized and published a journal or appears to have had aspirations to do so; communication was kept on the level of correspondences between the academicians and Leopoldo de' Medici and their individual networks; the production of knowledge had a double purpose of establishing matters of facts and producing cultural power for the benefit of the Medici family.[5] All of these characteristics are indications that natural philosophy in the latter part of the 17th century was not in general moving in the same direction or with the same pace across Europe. According to James E. McClelland III, the *Cimento* is an example of what he has called a "Renaissance academy."[6] His definition of the "Renaissance academy" includes a comparatively short existence and a close connection to a patron. Consequently, he describes the "Renaissance academy" as "relatively unimportant" in the larger history of scientific societies. McClelland does however acknowledge the *Cimento*'s position as part of "the organizational revolution" in the 1660s alongside the *Royal Society* of London and the *Académie royale des sciences*.[7]

The most distinctive characteristic that sets the *Cimento* apart from the other two organizational prototypes is the role of the patron and the Medici brothers' connection to the running, production and termination of the academy.[8] This left the *Cimento* somewhere in between the Baconian *aspirations* of the Royal Society, the Baconian *organization* of the *Académie des sciences* and the "Renaissance academies" with their obligations to the court and their role as producers of culture. Or perhaps it is better to characterize the *Cimento* as taking place *before* the two bigger societies. At the beginning of the *Cimento* project in 1657 neither the *Royal Society* nor the *Académie* had begun to convey meetings or to conduct experiments in any official capacity. Instead, inspiration for the *Cimento* came from a tradition of existing academies already present in Florence and Italy.

Academies and societies had a permanent function in Renaissance Italy as places of a knowledge production different from the dogmatic and traditional

5 For the general history of the *Cimento*, I refer to Middleton, *The Experimenters: A study of the Accademia del Cimento*; Galluzi, "L'Accademia del Cimento," pp. 788–844; Beretta, Clericuzio and Principe (eds.), *The Accademia del Cimento and its European Context*.

6 See McClellan, *Science Reorganized*, pp. 2–3, 42–49. "Renaissance" should not be understood as a temporal category but as a type.

7 McClellan, *Science Reorganized*, p. 47. Here McClelland and Hahn agree.

8 McClelland argues that most scientific societies were organized on the model of either the Royal Society or the *Académie Royale de Sciences*. See McClellan, *Science Reorganized*, p. 1.

ways of the universities. As such, academies had distinctive social, cultural and political function through their explorations of new knowledge. For instance, experimental knowledge production did not hold a secondary position from the academic functions but shared an equally important place in Florentine culture. Since the rule of Cosimo I (1519–1574) and the increase in Medici power, the family invested their patronage with more purpose and intention, actively using their money and power to manifest their right to rule.[9] This was a strategy applied to recast the family as historically bound to the Tuscan culture and territory through the protection and support of the arts. Several artists such as Giorgio Vasari, were given the task of enhancing the Medicis' legitimacy as rulers of Tuscany, as the military power of the family declined and the necessity of this other kind of legitimization became even more apparent.[10] Another example of this strategy was the *Accademia della Crusca* founded by Cosimo I in 1582 and devoted to the conservation and promotion of the Tuscan language.[11] As protectors of the academy the Medici linked themselves to Tuscany and the preservation of the duchy in a public fashion through the publication of vernacular dictionaries. Furthermore, many Renaissance academies undertook investigations of the bizarre and extraordinary, in line with the specific interest in the abnormal also seen in natural collections and many court exhibitions.

While the tradition of academies devoted to art or studies of literature and philosophy had been a distinctive part of the Medici family's activities, academies engaged in the study of nature did not appear in Italy until the early 17th century, excepting a few, smaller academies.[12] This rise in scientific academies was due to an increasing interest in natural philosophy among scholars and patrons that made the realm of scientific enquiry and theory a new domain where the patrons could display their authority. However, by the end of the century they had mostly ceased to exist.[13]

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9 See Barzman, *The Florentine Academy and the Early Modern State*.

10 Goldberg, *After Vasari: History, Art, and Patronage in Late Medici Florence*. The main point in Mario Biagioli's *Galileo Courtier* is exactly to stress the existence of such legitimization through the arts. See Biagioli, "Galileo the Emblem Maker," pp. 230–258; Biagioli, "Galileo's System of Patronage," pp. 1–62; and Biagioli, *Galileo, Courtier: The Practice of Science in the Culture of Absolutism*.

11 Tosi, "The Accademia Della Crusca in Italy," pp. 289–303; McNeely, "The Renaissance Academies Between Science and the Humanities," pp. 227–258.

12 Michelle Maylander mentions three academies from before 1600 the members of which worked on science or medicine: The *Accademia Aldina* (1490/1495), the *Accademia degli Affidati* (1548) and the *Academia Secretorum Naturae* (1560). See Maylander, *Storia delle accademie d'Italia*. 5 vols. Also see Beretta, "At the source of Western science," p. 132.

13 See Findlen "Founding a Scientific Academy," p. 4. Apart from the *Cimento*, Findlen

According to the standard account, the history of the *Accademia del Cimento* began on 19 June 1657 with the first recording of a range of systematic experiments that would eventually lead to the publication of the *Saggi di naturali esperienze* in 1667.[14] The *Saggi* included descriptions of a series of experiments in natural philosophy. It was published under the protection of Leopoldo de Medici, brother of Grand Duke Ferdinando II, and in the name of the *Accademia del Cimento*. It was printed in 800 copies and distributed to notable people and societies around Europe as gifts. The publication also marked the conclusion of a project that had been at least ten years in the making and had now been completed. In the following, I analyze the composition and structure of the *Cimento* project.

Apart from the *Saggi*, the primary source of the *Cimento* narrative are the surviving diaries found among the so-called "Galileo manuscripts" located at the *Biblioteca Nazionale Centrale* in Florence. From these diaries, we can reconstruct the beginning and end of what has become known as the lifetime of the *Cimento*. However, experiments and natural philosophy were conducted at the Tuscan court many years before the beginning of the diaries. In many ways, they merely represent a more structured recording of a period of work rather than the lifespan of an academy.[15] All but a few of the experiments had already been concluded by 1662, but were then reproduced in the presence of Prince Leopoldo.[16] According to the diary in Galilean Manuscript 262, the final meeting of the academy was recorded on 5 March 1667.[17] This date has often been interpreted as the closing of the *Cimento*.

In studies dealing only peripherally with the *Cimento*, it is often described as Leopoldo de' Medici's academy.[18] This description, however, is far too narrow since experiments of many kinds took place at the Medici palaces on the

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mentions the *Accademia dei Lincei* (1603–1630), *Accademia Fisico-Matematica* (1677–1698), the *Accademia degli Investiganti* (1663–1670), the *Accademia della Traccia* (1666–ca. 1678) as the most noteworthy examples of academies that vanished before the turn of the century. A few such as the *Accademia degli Inquieti* (1690–1714) and the *Accademia degli Argonauti* (1684–1718) managed to survive a little longer.

14 The history of the *Cimento* is known from Middleton, *The Experimenters*, and Boschiero, *Experiment and natural philosophy in Seventeenth-Century Tuscany*.

15 Both of the Medici brothers had plenty of experience with academies, having re-established the *Accademia Platonica* in 1638 and Leopoldo functioning as protector of the *Accademia delle Crusca*. Furthermore, experiments and natural philosophy had almost become mandatory at the Tuscan court since the time of Galileo.

16 Middleton, *The Experimenters*, p. 67, also see pp. 57–58.

17 MS Gal 262, "5 Marzo", 1667, p. 177.

18 See for instance Biagioli, *Galileo Courtier*, p. 358.

initiative of both Leopoldo and Ferdinando II, often during the same periods and with the same group of participants.[19] The idea of two distinct groups each working for a Medici brother is not unlikely. Experiments had been going on at the court for several decades prior to the beginning of the *Cimento* experiments in 1657.[20]

Martha Ornstein, building on Tozzeti's work and Vincenzo Antinori's long preface to the 1841 reedition of the *Saggi*, argued that the *Cimento* was "merely the more formal organization" of the scientists that gathered around Leopoldo de Medici from 1651 onward.[21] But indications of such formal organization completely lack in the documents relating to the *Cimento*. Indeed, the publication of the *Saggi* was, from the outset, a strong motive for conducting experiments more frequently and regularly, for already on 13 October 1657, only four months after the beginning of the diary, Leopoldo wrote to Ismael Boulliau that he was working on a publication to the benefit of the Republic of Letters.[22] For this purpose the creation of an academy was needed in order to provide a credible scientific setting for the project. If, however, the *Cimento* indeed had patrons and regular (albeit at times intermittent) meetings, it still lacked the formal constitution, officers, election procedures and regular journal required to be considered a formal academy.[23]

3 Steno as a Court Philosopher

In 1666 Nicolaus Steno arrived at the Medici court. As we know, he arrived in Florence at a time when the experimental and practical work to appear in the *Saggi* had already been done and printing was in its final stages. Steno, apparently, came too late to take part in the activities. If, however, Steno did not contribute to the *Saggi*, his presence in Florence and connection with

19 Middleton, *The Experimenters*, pp. 46–50.

20 For a range of different descriptions of experiments in connection with the Medici court before, during, and after Galileo, see Goldberg, *After Vasari*; Middleton, "The Place of Torricelli in the History of the Barometer," pp. 11–28; Middleton, *The History of the Barometer*; Barzman, *The Florentine Academy*; M. Segre, *In the Wake of Galileo*.

21 Ornstein, *The Role of Scientific Societies in the Seventeenth Century*, pp. 94–95.

22 See Middleton, *The Experimenters*, pp. 65–66.

23 See McClellan, *Science Reorganized*, p. 43. A completely different interpretation is offered by Mordechai Feingold in "*The Accademia del Cimento* and the Royal Society," pp. 229–241. Feingold opposes the cultural interpretation of the *Cimento* and gives much more credit to the scientific activities of the group and of the Medici Court.

the academy members is still clearly visible in both correspondences and other publications. Targioni Tozetti mentions Steno on several occasions in his massive account of Italian science, some of which is based on descriptions in the biography of Steno published by the *Accademia della Crusca* in 1775.[24] There is a long-standing tradition in Steno scholarship of including him as a member of the *Cimento*. This undoubtedly stems from the otherwise invaluable biography by Gustav Scherz in which Steno is cast as a member:

> The question [of whether Steno was a member] can be answered in the affirmative with great reliability [...]. Stensen was in active personal dealings with different members. He took part in the sessions and worked for the academy with the agreement of Prince Leopold [...]. In any case he was more justified as a member of the *Cimento* than as a member in the language academy of the Crusca [...].[25]

Scherz' primarily supported this claim by reference to Raffaelo Caverni's six-volume *Storia del metodo sperimentale in Italia* from 1891–1900: "Caverni solved the question [i.e. problem, JBT]" by expanding the existence of the *Cimento* from 1642 until 1675.[26] In his analysis, there had been two periods of the academy before the official period between 1657–1667, and a final period from 1667–1675, during which Steno was an important member.[27]

Regarding the Caverni-Scherz suggestion, it seems unnecessary to maintain that the *Cimento* was anything more, or took place for any longer, than the activities described in the dairies in the Galileo Manuscripts. There is simply no evidence to suggest otherwise. More importantly, however, one can simply consider what Steno himself said about the matter. On 14 January 1667 he wrote to Leopold de Medici, who had recently been appointed cardinal, thanking him for a copy of the *Saggi*. In his polite formulas of gratitude he also implied that the academy had come to an end:

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24 Tozzetti, *Notizie degli aggrandimenti delle scienze fisiche accaduti in Toscana nel corso di anni LX del secolo XVII, etc.* 3 vols., p. 211, 214, 448, 521. See also Manni, *Vita del Niccolo Stenone*.

25 G. Scherz, "Biography of Nicolaus Steno," in KM, p. 148.

26 Op. cit.

27 Scherz put forward his assertion about Steno membership of the *Cimento* member on other occasions as well. See for instance Scherz, "Niels Stensen's Geological Work," p. 18, and Scherz, "Nicolaus Steno's Life and Work," p. 25.

> The little weight my weak judgement may have does not permit me to advance the praises such a perfect work deserves, especially not in a time when the greatest minds of all the experimental academies show an ambition to celebrate the noble endeavor of the *Accademia del Cimento*, while they feel great pain in seeing a study from where great advances in natural investigations, made in little time, stopped by unforeseen accidents, and from where much promise could have been had in a continuation.[28]

There seems to be little doubt that, at this point, the *Cimento* was over.

One of the best sources we have for assessing Steno's *Cimento* affiliation is a report to Leopoldo from Antwerp on January 6 1668 that Lorenzo Magalotti wrote during a promotional tour to England.[29] Magalotti begins his letter by addressing the state of the *Cimento* and then mentions the "honorable solution" that he understood Steno's conversion to be. In Magalotti's view, Steno would be the perfect replacement for the departing Alfonso Borelli whom Magalotti found "*intollerabile*."[30]

There is no defining moment where it is possible to irrefutably state that Steno was a member of the *Cimento* project. But there is good evidence that he participated in the dissections of, and experiments on, animals and that he witnessed some retesting of the experiments that had found its way into the *Saggi*. In the *Elementorum Myologiae Specimen* that Steno wrote during his first year in Italy, there are some references to the experiments and members of the *Cimento*. In the dissection of the—now famous—great white shark,

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28 Steno to Leopoldo, 14 January 1668, EP I, n° 30, pp. 196–197. Also in MS Gal. 315, f. 1014^{r}–1015^{v}: "La poca stima, ch' al mio debole guidizio si deve, non mi permette passare più Avanti nelle lodi ch' ad un opera così perfetta convengono; principalmente nel tempo, dove li più grandi ingenii di tutte le accademie esperimentali mostrano una particular ambizione nel celebrare la nobile impresa dell' Accademia del Cimento, non senza grandissimo dolore riguardando da non sperati accidenti impedito uno studio, dal quale I grandissimi avanzi fatti in poco tempo nelli ricercamenti naturali danno ad ognuno chiari indizii di quello che dalla sua continuazione sarebbe stato da sperare."

29 Fabroni, *Lettere inedite di Uomini illustri*, vol. I, pp. 295–297: "Gli avvisi de quail mi onora V.A. nell'umanissima sua de' 29. Novembre venutami a trovare all'Aia son tutti curiosissimi, ma fra gli altro quello dell'onorata risoluizone de Mr Stenon è per se solo bastante a riempirme il cuore d'una gioia infinita essendochè oltre al motivo, che ho di rallegrarmene per il di lui vero bene, vi consider oil godimento che ne avrà ritratto lo zelo impareggiabile di V.A., e l'acquisto che mi presuppongo sia per farne cotesta Corte per infintanto che egli avrà vita."

30 Op. cit.

Steno refers to an experiment that Magalotti spoke to him about and which demonstrated the effect of heat on the expansion of metals.[31] The experiment was included in the *Saggi*.[32]

There are other *Cimento* members included in the dissertation on the shark head. In the introduction, Steno acknowledged the help he had received from Carlo Dati in acquiring the illustration of a shark's head from Michaelis Mercati's book *Metallotecha Vaticana*.[33] Redi's name was also mentioned. More importantly, however, Redi's own accounts of his collaborations with Steno are evidence of their joint experiments at the court.[34] A final example of Steno's specific connections with the *Cimento* is the ending statement of the *Elementorum Myologiae Specimen*, where Viviani was called upon as a witness to, and to participate in, the entire work.[35]

This is the closest we get to including Steno as a "member" of the *Cimento*. It is important to keep in mind, however, that the *Cimento* had no members' lists or official charters. Participants were picked from the circles within the reaches of the court to combine their intellects and strengths in a project that was not the beginning or the end of natural philosophy at the Medici court. From this perspective, Cavani's description of the Cimento as defined by its members is quite correct. It was however not the *Cimento* that extended across three decades but the "scientific" activities at the court. Natural philosophy and experiments were produced before 19 June 1657 and continued after 5 March 1667. But the project we refer to as the *Accademia del Cimento* involved only those members that are identifiable in the diaries or in obvious connection with them. Even membership does not provide an adequate demarcation of the *Cimento*.[36] The only member who was truly irreplaceable was the prince. "The prince" here should be read literally because, following Leopoldo's appointment as Cardinal in December of 1667, Ferdinando II became the primary

31 See OP II, p. 138.

32 The experiment can be found in Magalotti, *Saggi di naturali esperienze*, p. CLXXXIII. Middleton has established the dates for these experiments as 3 December 1657 and 10 January 1662, which was many years before Steno arrived in Florence. See Middleton, *The Experimenters*, p. 210.

33 See OP II, pp. 115–116.

34 See Francesco Redi to Steno, 4 February 1667, EP I, n° 22, pp. 188–190; Redi, *Experiments on the Generation of Insects*, p. 86.

35 See OP II, p. 154.

36 On the membership flux, see Meli, "Authorship and Teamwork around the Cimento Academy," pp. 65–95.

instigator of knowledge production from 1668.[37] A good example is Steno's geological work following the famous dissection of the great white shark.[38] As seen in the introduction to the *Prodromus*, Ferdinando II had encouraged and promoted Steno's geological work, which left Steno all the more nervous that he would not be able to pay his debt in the first instance.[39] Both Ferdinando II and his son Cosimo III encouraged Steno's geological studies and requested his assistance with the royal mineral collection.[40]

4 Philosophical Experiments

While there is no scholarly need to include Steno as a *Cimento* member he was no less a part of the Medici Court and influenced by their practices. To illustrate this, I now turn to analyzing the methodology and knowledge production of the *Cimento*'s members. Their *historical* approach had two advantages: it provided a method of producing knowledge without reference to causes and, as a consequence of this, it suited the conventions of working under patronage well, since it could never relate the Court to any particular philosophy.[41]

In his dedication to Grand Duke Ferdinando II, the *Cimento* secretary Lorenzo Magalotti placed the work of the *Cimento* in its proper courtly context:

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37 Leopoldo's continued interest in natural philosophy has been described by Middleton (see *The Experimenters*, pp. 324–325). We also find evidence of it in Steno's correspondence. See Steno to Leopoldo, 4 January 1668, EP I, n° 29, p. 195; Steno to Leopoldo, 14 January 1668, EP I, n° 30, pp. 196–197; Steno to Leopoldo, 4 February 1668, EP, n° 33, pp. 200–204; Steno to Leopoldo, 4 February 1668, EP I, n° 34, pp. 204–205; Steno to Leopoldo, 22 December 1668, EP I, n° 37, pp. 206–207; Steno to Leopoldo, 22 July 1670, EP I, n° 51, p. 219. While this provides further support to the thesis concerning Leopoldo's continued interests in natural philosophy, Steno however also addressed more and more of his letters to Ferdinando II and, from 1670 onward, to Cosimo III. See Steno to Ferdinando II, 12 May 1669, EP I, n° 39, pp. 207–208; Steno to Ferdinando II, June 1669, OP II, pp. 227–237; Steno to Ferdinando II, 3 August 1669, EP, n° 43, p. 210; Steno to Cosimo III, summer 1671, EP I, n° 62, pp. 238–241; Steno to Cosimo III, 19 August 1671, EP I, n° 63, pp. 241–245. Gradually these letters came to concern Christian philosophy and faith rather than natural philosophy.

38 As presented in the *Canis Carchariae*. See OP II, pp. 113–145.

39 OP II, p. 184: "[…] illi, ne foro cedere teneantur, cum non habeant, qvae solvant, solvunt ea qvae habent; et ego qvandoqvidem, qvae exhibenda tibi essent, omnia exeqvi neqveam, ne verba dedisse videar, eorum, qvae exeqvutus sum, praecipua exhibebo."

40 See Scherz, "Nicolaus Steno's Life and Work," in KM, pp. 189–199.

41 "Historical" in this sense does not refer to a sequential listing of events, but to experiences and observations of nature. See note 61 below.

> [The Saggi] will itself carry to those regions of the world where virtues shine most brightly, as a new testimony of the great generosity of Your Highness and reflect upon you a new sense of gratitude from the true lovers of the fine arts and the most noble knowledge.[42]

The dedication shows the how general purpose of the *Saggi* was to bring a *sensi di gratitudine* towards Ferdinando II from those virtuous places of the world where art and knowledge was highly appreciated. Most likely these places were centered in Paris and London with their respective academies. The inclusion of *bell'arti* is a direct indication of the broader cultural context into which natural philosophy and experiments fell. The intention of the *Saggi* was not solely to address natural philosophers and experimental academies but also the European courts where art and letters were held in high esteem.[43] This again points to the specific understanding of natural philosophy and true knowledge that was dominant at the Medici court. While the *Saggi* was described as *nuove Filosofiche speculazioni*, its contents were aimed at a much wider audience, where knowledge was produced without reference to causes.[44]

A crucial part of the *Saggi* is Magalotti's preface to the reader, which serves as a testimony to the patronage culture in which the *Cimento* was embedded and as evidence of the natural philosophy the Medici wished to display.[45] It is important to keep in mind that while the experimental approach was genuinely supported by the Medici, the anonymous voice of the *Cimento*, which rings in perfect unison throughout the *Saggi*, was not a reflection of the reality at the Pitti palace. There were strong tensions between for instance Borelli and

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42 Magalotti *Saggi*, p. [1]: "[…] è una cosa stessa che recar nuova testimonianza a quelle regioni del mondo, dove la virtù più risplende, dell'alta munificenza dell'A. V., e richiamare verso di lei a nuovi sensi di gratitudine i veri amatori delle bell'arti e delle scienze più nobili" (transl. modified from Middleton, *The Experimenters*, p. 87).

43 The style of the *Saggi* has been discussed by others. See Middleton, *The Experimenters*, p. 82; Fermi, *Lorenzo Magalotti, scienziato e letterato, 1637–1712*, pp. 91–94; Beretta, "Lucretius as Hidden Auctoritas of the Cimento," pp. 1–16; Miniati, "Lorenzo Magalotti (1637–1712): rassegna di studi e nuove prospettive di ricerca," pp. 31–47. The publication of the *Saggi* in Italian rather than Latin testifies to the Medicis' promotion of the Tuscan language. From Steno we also have a direct illustration of these sentiments, since he excused himself for not being able to write *De solido* in Italian, even though he realized that it would have been pleasing to both the Grand Duke and the *Accademia della Crusca*. See OP II, p. 186.

44 Magalotti, *Saggi*, p. [3].

45 Jay Tribby has analyzed the *Saggi* proem in "Of conversational Dispositions and the Saggi's Proem," pp. 379–390. His analysis is very much in agreement with my own.

Viviani and divisions between the peripatetics and the rest of the group have been closely studied as a cause of much unrest between the academicians.[46]

The original preface is 7 pages long. It contains no paragraphs or sections and jumps back and forth from general statements to accounts and descriptions of the *Cimento*'s specific approach and the role of Prince Leopoldo. For interpretive purposes it can be divided into smaller sections, each dedicated to a specific topic. The first part concerns the question of *truth*.[47] The second part concerns *production of knowledge* at the academy and is equally a praise of Leopoldo's contribution.[48] The third and final part deals with *strategy* and is entirely devoted to the reservations at the academy regarding statements about causes.[49]

As a governing concept the idea of *truth* was described as the binding structure of the universe upon which "*il maestro eterno*" had based his work. However, in the attempt to understand the world, man had wrongly believed that he had seen the truth. In reality he had created a number of false statements about the world. Like Icarus on borrowed wings, man is described as gaining the ability to improve intellectually but unable to maintain and uphold an understanding of the workings of nature.[50] In effect, man is unable to provide proper explanations of the causes of things in nature: "Meanwhile [man], improperly attaching causes to effects, does neither take the true essence from the one or the other, but makes a connection in himself forming false knowledge."[51] By promoting this rather high-strung analogy the academy displayed themselves as maintaining a "public" service and thereby legitimized their work. This is a clear example of the academy's official position, which was formulated in

46 These tensions have been discussed in Middleton, *The Experimenters*, pp. 310–316; Boschiero, *Experiment and Natural philosophy*, pp. 69–70, 94–98; Beretta, *At the Source of Western Science*, pp. 144–146.

47 This section includes everything from "Primogenita" to "preso qualche sapore" (line 4, p. 4 of the preface).

48 This section of the preface goes from "Non è per tanto […]" (line 4, p. 4) to "[…] stampano questi saggi" (line 7, p. 6).

49 This section includes the last part of the preface (line 8, p. 6, to the end of p. 7).

50 Magalotti *Saggi*, p. [6]: "[…] cominciò su quelle a levarsi; e tutto che oppresso dal peso del material corpo, facendo forza in su l'ali, per innalzarsi più alto che non conduce la scala delle sensibili cose, tentò quivi di fissarsi in un lume, che ricevuto negli occhi non è più quello, ma smontando s'intorbida e muta colore" (transl. modified from Middleton, *The Experimenters*, p. 89).

51 Magalotti, *Saggi*, p. [6]: "[…] mentre, adattando egli impropriamente le cagioni agli effetti, non toglie a questi o a quelle la verità del lor'essere, ma forma in sé medesimo dell'accoppiamento loro una falsa scienza."

opposition to scholastic philosophy. True knowledge could not be achieved through philosophical speculation alone but had to rely on experiment and observation. It required a different philosophy altogether.

The method of knowledge production they employed stood out as both a dismissal of Cartesian rationalism and a defense of experimentalism. Descartes believed that the natural world could be understood "mathematically" by applying to it methods based on those of algebra and geometry. The *Cimento* members were familiar with the importance of geometry as *a priori* true knowledge. Here true knowledge could be perceived independently of observation.[52] However, the problem with geometry was that it provided insufficient answers to the questions of natural philosophy: "The fact is that geometry leads us a little way along the road of philosophical speculation, but then abandons us when we least expect it."[53] Calculations and speculations would only deliver hypotheses regarding a given problem, but never supply evidence of matter of fact, which is why the academy argued for the necessary reliance on experiment. Nevertheless, the members of the *Cimento* were cautious never to exaggerate the importance of experiment. In order to rely on it as an approach to "*la verità manifesta*," multiple observations were necessary. Before any certain results could be achieved, a range of falsehoods would present themselves to the experimenters. Therefore reason (*mestieri l'intendersi da maestro*) and personal judgment (*proprio giudizio*) should be the guiding principles in the evaluation of the results. Geometry, in other words, could generate hypotheses but never be used for the *verification* of true knowledge. The establishment of true knowledge took place through multiple experiments whereupon truth would be realized. The *Cimento* operated from an understanding of nature in which one divine truth was present. Previously, this truth had been sought through the use of philosophical speculation but now experimental practice established this truth by demonstration. The consequences of this were double. On the one hand, it deflated the purely philosophical authority of truth and *sciencia*; on the other hand, it tried to establish experimental practice as a com-

52 See Shea, *The Magic of Numbers and Motion*, pp. 44–45; Davis and Hersh, *The Mathematical Experience*, pp. 325–326. It is likely that the references to geometry are directed at Descartes, despite Galileo's strong advocacy for its use in natural philosophy. In the *Saggi* preface, however, geometry is described as a necessary yet inadequate skill. But the academy members were very devoted to Galileo and it is improbable they would argue against him.

53 Magalotti *Saggi*, p. [7]: "Il fatto è, ch'ella [la geometria] ci conduce un pezzo innanzi nel cammino delle filosofiche speculazioni, ma poi ella ci abbandona in sul bello […]" (transl. in Middleton *The Experimenters*, p. 90).

parable authority on nature's truth, thus legitimizing its practice and worth. These aims were also apparent in the *Cimento*'s renunciation of speculation regarding causes, which was both part of the production of knowledge and of the Medici defensive strategy.

Finally, we consider the *strategic* part, which is the most extensive and telling of the three. It insists upon complete neutrality with regard to any disputes arising from the results presented in the *Saggi*:

> Finally, before anything else we declare that we would never wish to pick a quarrel with anyone, enter into subtle disputes or in vain contradictions; and if sometimes in the passage of one experiment to another, or for another reason, some small sign of speculation is given, this is always to be taken as the opinion or particular meaning of the academicians, never that of the Academy, *whose only foundation is to experiment and report*.[54]

This was not a rhetorical or modest statement. It was a specific *demarcation* of the natural philosophy at work in the Cimento—or the "façade" presented by the academy as Boschiero has called it.[55] The message conveyed towards the end of the preface is perhaps the clearest indication of how the Medicis wanted to work: by demonstration rather than speculation. This related partly to Leopoldo's awareness of possible ecclesiastical censorship and his reluctance to provoke the church. During the lengthy editing process of the *Saggi* Leopoldo wrote to Magalotti with specific orders regarding the Catholic Church: "I prefer that the manuscript be sent through Cardinal Ranucci. I warn you that nothing will be printed against his wishes."[56]

The academicians were well aware of the necessity of adopting a specific style in the presentation of the *Saggi*. Borelli, Viviani and Rinaldini were assigned the task of reading through Magalotti's drafts and comment on the contents before they were sent to the censors. Borelli wrote in his comments to the draft that: "I want to consider whether all the following discussion could

54 Magalotti *Saggi*, p. [10]: "Resta per ultimo, che avanti d'ogn'altra cosa ci protestiamo, di non voler imprender mai brighe con alcuno, entrando in sottigliezza di dispute o in picca di contradizioni: e se talora per far passaggio da una ad un'altra esperienza, o per qualunque altro rispetto, si sarà dato qualche minimo cenno di cosa specolativa, ciò si pigli pur sempre come concetto o senso particolare di Accademici, ma non mai dell'Accademia; *della quale unico istituto si è di sperimentare e narrare*" (emphasis mine; transl. modified from Middleton, *The Experimenters*, p. 92).

55 Boschiero, *Experiment and Natural philosophy*, p. 184.

56 Op. cit., p. 192.

be omitted, as it does not produce experiments, but opinions and counter-arguments of the things that could be noticed against the pressure of fluids."[57] In Borelli's opinion the *Saggi* should display unity rather than disagreement. As described by both Boschiero and Galluzzi, Viviani had the same understanding as Borelli.[58] He realized that the diverse opinions of the academicians regarding the vacuum and the pressure of the air could harm the academy, the Medici and the academicians themselves if the *Saggi* conveyed the impression of a divided group. The result was a discourse on narration. Borelli emphasized the "historical narration" on several occasions in his editorial comments.[59] On one occasion he expanded the literary style to a methodological approach, "wishing to point at the *historical method* used in all this writing."[60] This is a good indication that Borelli knew about the tradition of *historia* and that the *Saggi* adopted this approach in its presentation of the experiments.[61]

The genre referred to as *historia* was an anti-scholastic approach to philosophy and knowledge originating in the humanistic teachings in Italy during the early modern period. Traditionally, natural philosophy was considered the truest form of knowledge that could be had about nature. However, people worked with many forms of natural knowledge in the 17th century and did not always think along the lines of these categories. They took natural history, medicine and anatomy to be parts of natural philosophy. Hence, the Aristotelian focus on causes was challenged by new approaches to knowledge based on sensory experience and multiple observations. The historia genre

57 MS Gal 267, f. 18^{r}: "Pongo in considerazione se tutto il seguente discorso sia bene tralasciarlo non arrecandosi esperienze, ma opinioni e riposte alle cose che si potrebbero osservare contro la pressione de fluidi."

58 Boschiero, *Experiment and Natural philosophy*, pp. 185–186; Galluzzi, "L'Accademia del Cimento," p. 809.

59 See MS Gal 267, f. 18^{v}, 19^{r}, 21^{r}. See also Boschiero, *Experiment and Natural Philosophy*, pp. 185–187.

60 MS Gal. 267, f. 19^{r}: "Volendo osservare il *metodo istorico* usato in tutta questa scrittura […]" (emphasis mine).

61 Boschiero also identifies Borelli's *metodo istorico* as a well-known contemporary presentational technique, which bestowed authority and credibility on the academy (see Boschiero, *Experiment and natural philosophy*, p. 188). He does, however, seem unaware of the scholarship concerning the *historia* genre and the implications it had for natural philosophy. I have described the *historia* genre in relation to Steno in Bek-Thomsen "From flesh to fossils," pp. 289–306. The best resources on the *historia* genre remain Pomata and Siraisi, *Historia: Empiricism and Erudition in Early Modern Europe*; Grafton, *What was History?*; Grafton, "Historia and Istoria: Alberti's Terminology in Context," pp. 37–68.

reached into both the humanistic reappraisal and reinterpretation of antique knowledge and the growing attention to experience that was transforming natural philosophy.

Borelli's statements quoted above point to the fact that while maintaining a strictly narrative presentation of experiments avoiding any reference to philosophical causes, the *Saggi* managed to produce valid form of natural philosophy comparable to other forms of traditional (scholastic) natural philosophy. The description of experiments in meticulous detail was also intentional, as it aimed at presenting the reader with the "narration of facts" (*narratione d'un fatto*).[62] The experience of the reader was of capital importance to Borelli who felt strongly about the reception of the experiments:

> It seems to me that these experiments, although beautiful, should be handled in such a way that, in their sequence and historical narration, they present such diligent and fine judgement that the curiosity *of the reader* should have nothing to desire.[63]

The satisfaction of the reader required a precise and accurate description of any detail needed to reproduce the experiment. Such descriptions were fundamental in the *historia* genre, where the cumulative particular narration of observations provided the evidence of facts.[64]

5 Steno's *Historia*

That Steno felt closely connected to the Florentine Court is not only evident from his correspondence and lasting relationship with the Medici family. It can equally be detected in his geological studies at the end of the 1660s. Before he came to Tuscany, Steno never used *historia* as deliberately and methodolog-

62 Boschiero, *Experiment and Natural Philosophy*, p. 186, note 22.

63 MS Gal. 267, f. 21r: "Parmi che queste sperienze benchè belle debbono essere maneggiate in modo che, nella seie e racconto storico de esse, so scorga industria e finezza tali di giudizio che la curiosità *del lettore* non vi abbia nulla da desiderare" (emphasis mine; transl. modified from Boschiero, *Experiment and natural philosophy*, p. 187).

64 As noted by Boschiero there are many similarities with this rhetorical strategy of the *Cimento* and that of the Royal Society, more specifically that of Robert Boyle. Despite these similarities there are no apparent connections, which would imply that the strategies had a mutual origin. See Dear, "Totius in Verba: Rhetoric and Authority in the Early Royal Society," pp. 145–161; Shapin, "Pump and Circumstance," pp. 481–520.

ically as he did in the *Canis Cachariae* and the *Prodromus*. Here, I will focus exclusively on the *Prodromus*.

The *Prodromus* has 78 pages and is divided into 4 parts. The dedication to Ferdinando II explained it as "*veram rerum cognitionem per experimenta*," i.e. "true knowledge of things through experiments." This characterization directly prolonged the *Cimento*'s call for *la verità manifesta*.

The first part, the shortest, summarizes the then current knowledge about the problem of *glossopetrae*, i.e. the mystical tongue stones found all over Southern Europe. According to Steno, the ancients had already been asking the right questions, but the origin of *glossopetrae* was a modern problem: "Only one such difficulty troubles the ancients, namely the way in which marine objects had been left in places far from the sea [...]. In more recent times [...] almost everyone was busy inquiring into the origin of said bodies."[65] The question at hand concerned the place where certain natural objects were originally created in relation to the location of those object upon discovery. By going through a range of historical observations, Steno wanted to pile up evidence for his own analysis, but did not want to take a stand with regard to the underlying philosophical implications:

> For what I have stated about matter holds everywhere, whether matter is considered to consist of atoms or of particles which may change in a thousand ways, or of the four elements, or of as many different chemical elements as are needed to meet the variety of opinions among chemists.[66]

Rather than providing specific names, Steno here refers to philosophies that would be easily identifiable to the reader as, respectively, atomistic, Aristotelian, humoural, and chemical, in the various forms that the latter took in the 17th century.[67]

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65 OP II 11, p. 186: "Antiqvos unica tantum exercebat difficultas, nempe qvomode res marinae in locis a mari remotis derelictae fuerint [...] Recentioribus seculis parcius urgebatur Antiqvorum difficultas, cum omnes fere circa ortum praedictorum corporum indagandum occuparentur" (transl. in Scherz *Steno. Geological Papers*, pp. 141–143).

66 OP I, p. 189: "Qvae enim de material asserui, ubiqve locum habent, sive qvis pro material habuerit atomos, sive particulas mille modis mutabiles, sive qvatuor elementa, sive principia chymica, qvantumlibet pro Chymicorum varietate varia statuantur" (transl. in Scherz, *Steno. Geological Papers*, p. 147).

67 Scherz offer more specific references to the alleged origin of the references. See Scherz *Steno. Geological Papers*, pp. 220–234. Miniati has a slightly different interpretation here as

Similar to the *Cimento*, Steno was reluctant to address the question of the *causes* of his results. It is important here to distinguish between a causal conclusion and an observational conclusion because each kind refers to a specific form of knowledge production. Steno made no causal conclusions from his observations in *Prodromus* but stated that his work may "provide an opportunity for others, who from their own wish have the use and enjoyment of leisure, to cultivate studies in physics and geography with greater profit."[68] This testifies to a methodological approach to knowledge that stops short of making philosophical conclusions. Steno had a very clear understanding of the ways in which natural philosophers could produce trustworthy knowledge:

> considering the natural world those things which cannot be determined with certainty are not kept separate from those that can be so determined; as a result, the principal schools of philosophy are reduced to two classes; some indeed are prevented by scruples from putting faith even in demonstrations, for fear that the same error exists in them that they often detect in other declarations; others, on the contrary, would by no means show themselves constrained to hold as certain only those things in which people of sound mind and sound perception could express belief, they being of the opinion that all those things are true that seem to them beautiful and ingenious.[69]

Once again, we see how Steno's thoughts corresponded to the Cimento approach. In an attempt to avoid the opposition between scholastics and experimentalists, he chose the middle ground, taking inspiration from Seneca's moral philosophy.[70] Moreover, he intended only to demonstrate knowledge that was already accepted by all branches of early modern natural philosophy: "[I]t may

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he interprets Steno's view on matter as fundamentally different from other corpusculastic theories and thus not very cautious (see *Nicholas Steno's challenge for truth*, pp. 272–273).

68 OP II, 185: "Nescius iatqve, qvae alia experimenta studiaqve alibi me maneant, optimum factu ratus sum *de solido intra solidum naturaliter incluso* ea hic exponere, qvae, pro acceptis beneficiis, grai animi mei pignus tibi erunt, et otio suo ex voto fruentibus aliis occasionem praebebunt Physices et Geographia studia majori cum fructu excolendi" (transl. in Scherz, *Steno. Geological Papers*, p. 139).

69 OP II, p. 187, transl. in Scherz *Steno. Geological Papers*, p. 145. Scherz has argued that this specific part is in reference to the Galileo affair. However, without additional support of the argument, it may just as well be a strategically defensive measure by Steno. See Scherz, "Nicolaus Steno the Humanist," p. 297.

70 OP II, p. 188: "Ut itaqve et hunc scopulum evitare qvod de morum praeceptis *Seneca* saepius inculcat, in Physicis summopere urgendum judicavi: ea ille morum praecepta

be evident that no philosopher exists who does not say the same thing, though not always in the same words, or if he has spoken differently, nevertheless admits those points from which these details necessarily follow."[71] In light of the *Saggi*, it is interesting to note how Steno's appeal to *experimentis simul et rationibus demonstrata* established a connection to the kind of reasoning that could also found among many of the humanist natural philosophers who used the *historia* genre.[72] Moreover, it brings to mind the preface of the *Saggi* in which experiment guided by reason was also put forward as a means to acquire true knowledge. Clearly, Steno was not writing as an anatomist or court physician but as a natural philosopher.

In the second part of *Prodromus*, Steno described his theory of how to interpret the observations made in nature and provided a method for determining the order in which solid bodies had been enclosed in other solid bodies. In conclusion, Steno stated that if a solid body had been produced according to the laws of nature (*Naturae leges productum est*) it was produced from a fluid. Next, by applying three simplified steps, Steno arrived at his methodological theorem:

> Therefore, if at least all solids have grown from a fluid, if bodies mutually alike in all respects were also produced in the same way, if of two solids mutually in contact the first to harden was that which impresses its surface characteristics on the other surface, it will be easy, given the solid and its location, to make a definite statement about the place of its production. And this is indeed a general consideration of the *solid enclosed by a solid*.[73]

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optima esse ait, qvae comminia sunt, qvae publica; […]" (transl. modified from Scherz *Steno. Geological Papers*, p. 147).

71 OP II, p. 189: "Haec ego singula in ipsa dissertatione fusius expono experimentis simul et rationibus demonstrata, quo pateat, neminem Philosophorum esse, quin vel idem dicat, licet non semper iisdem verbis, vel, si diversa dixerit, ea tamen admittat, unde haec necessario seqvuntur" (transl. in Scherz *Steno. Geological Papers*, p. 147).

72 OP II, p. 189.

73 OP II, p. 196: "Qvod si itaqve omne solidum e fluido saltem incrementa habuit, si corpora sibi invicem omnino similia simili etiam modo producta sunt, si e duobus solidis sibi invicem contiguis illud primo induruit, qvod alterius superficiei proprietates sua superficie repraesentat, facile erit, dato solido et loco, in qvo est, de loco productionis illus certum qvid pronuntiare. Et haec qvidem generalis consideratio est *solidi intra solidum contenti*" (transl. in Scherz, *Steno. Geological Papers*, p. 159).

Steno constructed his argument on the basis of indisputable, but particular facts. The truth of those facts was then consolidated through reference to other authors and authorities like Democritus, Seneca, and the Bible. One reference is of particular interest here, considering Steno's connection with the Medici court and the *Cimento*. For, in *Prodromus*, for the first time in his academic career, Steno made a specific reference to Galileo: "We are taught moreover by the most substantial proofs of the great *Galileo* that heavier bodies of this kind can remain on the top surface of a fluid [...]."[74] Within Danish Steno scholarship this has been taken as an indication of Steno's admiration for Galileo.[75] The reference to Galileo does indeed stand out in *Prodromus* as one among a very small number of named interlocutors. This cannot, however, be explained by mere admiration. In the context of the *Cimento* and the Medici patronage of Galileo, the reference is more likely a demonstration of gratitude towards his patron Ferdinando II and a display of respect for his protection of the great Galileo.

Steno's use of the *historia* genre comes into play in the third part of the *Prodromus* in which he describes his "experiments," i.e. the observations he had made during his travels in Italy. These descriptions also included an interpretation of the formation and strata of the earth as well as of the specific minerals and fossils discovered in the ground. From a patronage perspective, this part was the most important since it demonstrated how geological observations could be used as an instrument of cultural power by addressing, very concretely, the religious narrative in the Bible. The hills of Tuscany with its magnificent strata could become the physical witness of both Genesis and the Deluge.

These descriptions take up a substantial part of *Prodromus*. Steno provides an extensive list of observations concerning incrustations, strata, crystals, different shells and fossils, each followed by brief propositions on the subject. Thus listing observations followed by propositions is a way of proceeding that is strikingly similar to the descriptions of experiments found the *Saggi*. Steno stated his purpose at the end of his observations: "I have [...] indicated how from that which is perceived, a definite conclusion may be drawn about what is imperceptible."[76] In a sense, this phrase sums up Steno's whole idea about methodology and production of knowledge. In the annotated translation of

74 OP II, p. 20: "[...] solidissimae Magni *Galilei* demonstrations nos docent."

75 See Scherz, *Steno. Geological Papers*, pp. 229–330, note 105. Also see Kardel, *Steno: Life, Science, Philosophy*, p. 96.

76 OP II, p. 219.

Prodromus, it is even presented as the pinnacle of Steno's achievements in a manner that has since inspired many Steno studies:

> Steno is a tremendous "Autochthoner" (original thinker). The more admirable is his achievement, amounting to genius, since he was in no way inspired or encouraged by intellectual currents of his age, but, became the founder of geological thinking *completely* on his own, by means of clear, logical thinking and by following up problems which arose out of a comparison of recent living beings with fossils.[77]

The collaboration with the *Cimento* and close involvement with the Medici court is however a biographical and well documented fact that makes it difficult to sustain the conclusion that Steno's philosophical arguments resulted entirely from isolated genius. His methodology arose from awareness of experimental knowledge production and of the process of validating observed facts by means of rational argument. This was similar to the kind of knowledge production described in the *Saggi*. Similarly, his reluctance to provide final conclusions about his own conjectures was also closely related to his position at to the Medici Court, and testifies to his awareness of potential religious dangers of the *Saggi*. This is evident from the fourth and final part of the *Prodromus*.

From the viewpoint of cultural analysis, this is the most important part of *Prodromus*. It shows how Steno's theory could contribute to the cultural and religious history of the Tuscan landscape. Hence, Steno proclaimed, "how the present state of anything discloses the past state of the same thing is made evidently clear by the example of Tuscany."[78] As we have seen, Steno had made a point of explaining how he only made observations that others would agree with. This, in turn, was for him identical to demonstrating particular knowledge in a philosophical sense. In accordance with the *historia* genre, the demonstration of particular knowledge—the *demonstratio quia*—was not only a description of things. It was sufficient for making valid and truthful theories. As opposed to mathematics or medicine, natural philosophy was traditionally considered a higher form of knowledge and its products of an equally higher value. Steno's reservations about granting natural philosophy

77 Scherz, *Steno. Geological Papers*, p. 232, note 131. This line of thinking is also clearly present in Hansen, *Stregen i Sandet, Bølgen på Vandet*, esp. pp. 79–85. Kardel argues that Steno's concepts of truth and certainty differed from that of his contemporaries. See Kardel *Steno: Life, Science, Philosophy*, p. 88.

78 OP II, p. 219: "Qvomodo praesens alicujus rei status statum praeterium ejusdem rei detegit, prae caeteris suo id exemplo Etruria evidenter declarat."

such a status were near paraphrases of what Magalotti had written in the *Saggi* preface. They show how the *Prodromus* can and must be understood in the context of the patronage under which it was composed. By making use of a methodology that produced valid knowledge while abstaining from claims about causes (thus protecting his patron from possible religious objections), Steno's work could be used in the cultural context of the Medici court as a demonstration of power and knowledge.

6 Conclusion

According to a certain branch of contemporary Steno research, much of Steno's methodology can be described as a search for truth through "demonstrative certainty."[79] In 1673, this was Steno's own description of his method, using both reason and experiment to approach the truth in his studies of nature.[80] However, this method was not particular to Steno. The *historia* genre and the work presented in the *Saggi* bears witness to this.[81]

There are many indications that Steno's work in *Elements of Myology* and the *Prodromus* had much in common with the approach and presentation of the *Saggi* publication. The members of the *Cimento* relied on experiments as a species of demonstration. Steno used a multitude of observations from nature instead. As such, the *Prodromus* was not a mere description of the Tuscan landscape, or devoid of knowledge claims, despite Steno's reservations regarding his own conjectures and the absence of causal explanations. It was a very solid contribution to the form of knowledge production that already existed at the Pitti palace.

Finally, in conclusion, Steno's conversion and religious beliefs should briefly be taken into consideration. As work belonging to the productions of the *Cimento*, Steno's geological papers were designed to demonstrate the separation between faith and natural philosophy. They did not produce a situation of conflict with opposing arguments and conclusions. Rather, he pre-

79 Kardel, *Steno: Life, Science, Philosophy*; Hansen, *Stregen i Sandet, Bølgen på Vandet*; Hansen, "On the origin of natural history," pp. 159–178; Cutler, "Nicolaus Steno and the problem of deep time," pp. 143–148.

80 Steno used the term in his preface to the anatomical demonstrations in Copenhagen 1673. See OP II, pp. 249–256.

81 Kardel argues that the striving for demonstrative certainty was the norm for natural scientists, but goes no further into his analysis. See Kardel, *Steno: Life, Science, Philosophy*, p. 89.

sented to those two domains of knowledge as independent perspectives on different aspects of life.[82] Just as the *Cimento* took great care not to repeat the mistake of Galileo (i.e. to speak with certainty and not in hypothetical terms), Steno made an effort to avoid the "danger of novelty" by correlating his observations with Scripture.[83] Hence, Steno presented his geological work as being in agreement with Christian theology and sacred history, fully in line with Steno's beliefs. As argued by Stefano Miniati, the *Cimento* thus influenced Steno to produce a theory that could fit his observations without having to produce causal explanations.[84] And yet, Steno's belief in God as the first cause of motion constitutes an important element in his explanation of the transformations that matter undergoes during sedimentation.[85] Similarly, the theist belief in God's presence in the world was a central part of Steno's natural philosophy as presented in the *Prodromus*. Furthermore, the biblical chronology and time span was never put into question by his geological observations. Indeed, they tended to support them. If, however, Steno claimed complete agreement between the Bible and his own observations, he also stressed the constitutive limits of human knowledge in terms similar to those of the *Saggi*: "When man has performed most skillful things, he cannot, except through a fog, make out what he has done, which instruments he used, or through which cause the said instrument moves."[86] The *Saggi* presented truth as covered by several veils, confounding the natural philosopher in his work, making it difficult for him to recognize the first-born creature of divine wisdom.[87] In the *Saggi*, the solution to this problem could be found by combining geometry with experience. It was the exact same solution that Steno proposed in his work on myology. Steno's Christian beliefs are evident in his natural philosophy as a clear indication of how his geological work was

82 See Barbour, *Religion and Science*. It is difficult and unjustified to categorize Steno's position into one of Barbour's four relationship models. While Steno presented strong arguments against any potential controversies between his natural philosophy and religion, it is also certain that he understood the world including nature in religious terms. Also see Miniati, *Nicolas Steno's challenge for truth*, p. 192. For a discussion of Barbour's thesis, see Brooke and Cantor, *Reconstructing Nature*.

83 Miniati, *Nicolas Steno's Challenge for Truth*, pp. 276–278.

84 Ibid. p. 274. Miniati speaks of "metaphysical statements" rather than "causal explanations."

85 OP II, p. 189.

86 OP II, p. 189: "cum homo, ubi artificiosissima qvaeqve praestiterit, nec qvid egerit, nec qvo organo usus fuerit, ned qvid sit causa illa dictum organum movens, nisi per nebulam prospiciat."

87 Magalotti, *Saggi*, p. [6].

not detached from his religious life. And why should it be detached? When Steno investigated the strata of the Florentine hills in the Arno valley, he did so with the methodology and argumentation of an early modern anatomist observing the history of nature as it revealed itself to him layer by layer, stone by stone, fossil by fossil. What he produced was knowledge worthy of philosophical *scientia* and suitable as a patronage gift for the Medici court. His approach and reservations all originated from a solid understanding of the contemporary methodological discussions and court etiquette, while never losing touch with his religious beliefs and the truth revealed to him in the Bible. As such, Steno is an important example of an early modern natural philosopher whose career was never strange or peculiar but fitted right in at the Medici court.

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CHAPTER 10

Some Observations on Nicolas Steno as a Critical Reader at the Crossroads of Natural Science and Theology: André Martin and Giordano Bruno*

Frank Sobiech

1 Introduction

Regarding sources, the anatomist and father of modern geology Nicolas Steno (1638–1686) is one of the best documented scientists of the age of the Scientific Revolution. His unpublished scientific papers form part of the *Biblioteca Nazionale Centrale di Firenze*.[1] When leafing through the pages, one stumbles across excerpts from two philosophical books: The first one has to do with Steno's task as preceptor, i.e. teacher of the Florentine heir to the throne of the Grand Duchy of Tuscany, crown prince Ferdinando III de' Medici (1663–1713), whereas the second book was read by Steno in his last years as vicar apostolic in Hamburg. The following is a study of these excerpts in context.

Steno's papers are written on received letters, sheets of note paper and scraps. They were catalogued in the 19th century under the *Collezione galileiana*, the manuscripts of Galileo Galilei (1564–1642), with the *Posteriori di Galileo, Accademia del Cimento*, i.e. the scholars from the time after Galilei who were not his direct pupils. Though Gustav Scherz (1895–1971) used them for his edition of Steno's correspondence, he left out the main part of Steno's notes, perhaps because of their disorder.[2] Thus, from folio 76 onwards, they have not been edited so far, with a few exceptions.[3] Without any chronological or topical order, they approximately span the months after Steno's Paris *Discours sur l'anatomie du cerveau* on the anatomy of the brain (ca. February 1665,

* Another version of this paper, including a short analysis of Steno's unknown diary sheets, is included in Sobiech, "Simplicity of Faith, Intuition and Giordano Bruno," pp. 249–267. Some thoughts of the paper are also part of Sobiech, *Ethos, Bioethics, and Sexual Ethics*.

1 Biblioteca Nazionale Centrale di Firenze (BNCF), Gal. 291: "Scritti di Niccolò Stenone".

2 BNCF, Gal. 291, fol. 76^{r}–245^{v} (*missing*: fol. 125–135, 137–141). Some brief notices regarding the papers can be found in EP II, p. 907.

3 Cf. the first part of Gustav Scherz's posthumous biography of Nicolas Steno in KM, p. 46 (fig.) and p. 222 (fig.).

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published Paris 1669, in Latin Leiden 1672) up to his last years in Hamburg and Schwerin. It is possible to date the papers with the help of e.g. scattered envelopes, coats of arms and one previously unpublished letter in Steno's hand.[4] Containing titles and excerpts from books, they all deal with science and the relationship between science and faith.

2 Steno as Teacher of Natural Philosophy

Steno, who had worked as an anatomist in Copenhagen from 1672–1674, arrived in Florence at the turn of the years 1674/75.[5] On July 5, 1674, while still in Copenhagen, he had written to the Danish Lord Chancellor Peter Schumacher Griffenfeld (1635–1699)—the primary force behind his appointment to Copenhagen—that he was assigned by Cosimo III de' Medici (1642–1723), Grand Duke of Tuscany since 1670, to teach "*la philosophie naturelle*" (natural philosophy) to the Florentine crown prince.[6] Cosimo made it clear from the start that Steno should teach "Christian philosophy" (*philosophia Christiana*).[7] Due to the difficult situation for Catholics in Lutheran Denmark, Steno in the wording of his letter to Griffenfeld perhaps intended taking up the non-denominational

4 It might be possible to ascribe them to still existing letters: BNCF, Gal. 291, fol. 77a^{r} (to Mr Steno in Florence, in Italian), 87^{v} (to bishop Steno in Hamburg, in Italian, about mid-September 1683–December 11, 1685, coat of arms removed), 90^{v} (to bishop Steno in Hamburg, in Italian), 108^{v} (to bishop Steno in Hamburg, in Italian, with coat of arms), 117^{r} (draft of a letter to an unknown "Vir Clarus"; a review of the latter's writings by Steno in terms of the Christian faith), 117^{v} (to Mr Steno in Florence, in Italian, before 1672, coat of arms fallen off), 119^{r} (Florence, before 1672; Steno's note regarding the Florentine librarian Antonio Magliabechi as the owner of books that Steno had borrowed for his own theological publications, cf. ibid., fol. 119^{v}), 121^{v} (fictive address; calligraphic tryout in Steno's hand), 167^{v} (prefabricated envelope; to Mr Steno in Florence, in French, with coat of arms), 168^{r} (partially preserved; to Mr Steno [?] in Florence, in French), 169^{r} (to bishop Steno in Hamburg, in Latin, with coat of arms), 172^{v} (to bishop Steno in Hamburg, in Italian, with coat of arms), 191^{v} (letter paper, without address or recipient, with coat of arms), 214^{v} ("copy" [*copia*] of a letter of December 29, 1675, concerning "Giuseppe Almerigo dello Stato di Venetia", not in Steno's hand), 228^{v} (to bishop Steno in Hamburg, in Italian, with coat of arms), 239^{v} (beginning of a letter in Steno's hand with a cross and the address "Mademoiselle P"; not finished, after 1677, Germany), 240^{v} (to bishop Steno in Münster, in Italian, with coat of arms), 242^{v} (to bishop Steno in Münster, in Italian, with coat of arms).

5 KM, 290–291, 325.

6 EP I, n° 95, p. 293.

7 EP I, n° 120, p. 322, lines 32–35, here lines 34–35: "la philosophia Christiana."

natural-philosophical content of his Copenhagen inaugural address as an anatomist of January 29, 1673 (Julian Calendar).[8]

One day in early 1675, Steno took up his position as preceptor at 6 o'clock in the evening.[9] He shared his task with other men, e.g. Francesco Redi (1626–1698), Vincenzo Viviani (1622–1703) and the court theologian Giacomo Antonio Morigia CRSP (1633–1708).

When Steno began to teach, Ferdinando III was eleven years old; when Steno ended his duties, the prince was about 13 and a half. As an anatomist and natural researcher, Steno read and evaluated many books, made excerpts and added his own thoughts, unsolved problems and desiderata for the future, a method which he developed as early as in his Copenhagen *Chaos* diary (1659), written during his last year of studying medicine at the University of Copenhagen. In this diary, Steno decided to follow the methods of Francis Bacon (1561–1626) and René Descartes (1596–1650).[10] But Steno, in contrast to Bacon, did not focus so much on mankind's needs, but rather stressed mankind's ability to mentally appropriate his environment in order to conduct research and make decisions.[11] Steno was an independent thinker relying on his own observations and advocating a plurality of methods in science. He instructed his students that way in Copenhagen in 1672–1674.[12] In a paper on science and faith of the 1670s, Steno wrote that "nature" is a "teacher" to man.[13]

3 Steno as Scientist, Reader of André Martin

Let us now turn to the excerpts from two philosophical books found among Steno's papers in Florence. With respect to the first book, Steno took his notes and made excerpts on bad, now brownish, crumbly paper—apparently not Florentine rag paper—that does not exhibit any signs of previous use.[14] They deal

8 Sobiech, *Ethos, Bioethics, and Sexual Ethics*, 77–78.

9 In his letter (undated) to Vincenzo Viviani (EP I, n° 100, p. 300).

10 Steno, *Chaos. Niels Stensen's Chaos-manuscript*, ed. Ziggelaar, p. 124. Steno read a Latin translation (*De dignitate & augmentis scientiarum*, Leiden 1645) of Bacon's *Of the Proficience and Advancement of Learning, divine and humane* (London 1605). See Sobiech, *Ethos, Bioethics, and Sexual Ethics*, pp. 35–36.

11 I exemplify that through Bacon's *De sapientia veterum liber* (1609) in Sobiech, *Ethos, Bioethics, and Sexual Ethics*, pp. 64–65.

12 Concerning Steno's student Johann Valentin Wille (1651–1677), see ibid., pp. 158–160.

13 BNCF, Gal. 291, fol. 99^{r}–100^{v} (without title), here 99^{v}: "natura magistra."

14 Ibid., fol. 180.

with a contemporary book on "Christian philosophy" by the French Oratorian writer André Martin (1621–1695).[15] Martin had been professor at *Notre-Dame-des-Ardilliers* in Saumur until 1671; in 1674 Martin was denounced as defending Jansenism by an unknown person and, as a result of this, he was banned from teaching by royal secret order.[16] It is probable that Steno read the book during his time in Copenhagen (1672–1674), perhaps in the last months of the year 1674 with a view to his new task as preceptor in Florence.

Martin published his 5-volume *Philosophia christiana Ambrosio Victore theologo collectore, seu S. Augustinus de philosophia universim* under the pseudonym "Ambrosius Victor" (Paris: P. Promé 1667, Paris: Frédéric Léonard ^{2}1671, 6th vol. Saumur: F. Ernou [1671]). The work contains a compilation in 43 chapters of citations from the theologian, bishop and church father Augustine of Hippo (354–430), considered from a Cartesian perspective.

A sixth volume—published separately and added to the second edition of Martin's opus—bears the title *De anima bestiarum*. Steno cites it at the end of the densely-written leaf dedicated to the problem of animal souls.[17] Martin's opus is an attempt at depicting animals as "machines" that do not suffer, arguing that Augustinian principles support the rejection of animal souls.[18] As for his method, Martin explains that he will outline "not what he [i.e. Augustine] explicitly stated, but what necessarily results from nearly all his principles."[19] With respect to animal souls, on the leaf containing his excerpts, Steno refers both to the authority of the Bible and to "human experience."[20] On the basis of his experience with vivisection, Steno was convinced that animals do have—mortal—souls; he reflects upon the problem and finally mentions the "generation in human beings and animals" which is enabled by the soul.[21] He here clearly alludes to chapter 41 of Martin's work dealing with the heart rate and generation,[22] which must have interested Steno, since he had

15 See Lesaulnier, "Martin, André," pp. 722–724.

16 See Girbal, *L'Affaire du P. André Martin a Saumur*, pp. 24–30.

17 BNCF, Gal. 291, fol. 180^{v}: "Philosophiae Christianae Ambrosio Victore Theologo Collectore seu Sanctus Augustinus De anima bestiarum."

18 Concerning the term "machine" (*machina*) see [Martin], *Philosophiae Christianae* [1671], pp. 219–227 (chap. 38), pp. 228–237 (chap. 39). See also Girbal, *L'Affaire*, pp. 18–19.

19 [Martin], *Sanctus Augustinus de anima bestiarum*, ã2^{r}–ẽ6^{r} (Praefatio), here ã2^{v}: "non quod expresse asseruit, sed quod ex omnibus fere ipsius principiis necessario consequitur."

20 BNCF, Gal. 291, fol. 180^{r}: "humana experientia". On Steno's vivisections, see Sobiech, *Ethos, Bioethics, and Sexual Ethics*, pp. 61–62.

21 BNCF, Gal. 291, fol. 180^{v}: "generatio in hominibus et bestiis".

22 [Martin], *Sanctus Augustinus de anima bestiarum*, 242–244.

done research on the question.[23] Steno concludes: "*Notabene*, [decisive is] what in that field is proved necessary by the peculiar fundaments of the doctrine itself, not what he [= Martin] defined without perhaps any more rigorous examination from the prejudices of human convention alone."[24] Steno, who had been working on some treatises on the Bible and on faith in Florence since 1670,[25] nonetheless still felt more competent in the field of natural science than in theological speculation.

Steno's duties as a preceptor were probably reduced after his ordination to priesthood in the Florentine cathedral *Santa Maria del Fiore*, which took place on Holy Saturday, April 13, 1675.[26] In his sermon on the virtues of a Christian prince—probably delivered at the Florentine court in April 1677 before leaving for Rome on May 1, 1677—Steno states: "I had spent all my efforts and all my time except for my spiritual duties [e.g. being a father confessor in the Florentine Theatine church of *San Gaetano*] on that duty alone."[27] From February 17 to March 6, 1677, Steno attended presentations of dissected fish held before the crown prince each evening in Pisa.[28] On May 1, 1677 he departed for Rome where his appointment as Titular Bishop of Titiopolis and Vicar Apostolic of the Northern Missions and his consecration as bishop followed in September.

4 Steno as Bishop and Scientist, Reader of Giordano Bruno

The years in Germany from 1677–1686 as vicar apostolic were hard work for Steno as a former natural researcher new to the field of pastoral ministry. He first served at the Court of the duchy of Braunschweig-Lüneburg in Hanover; from 1680–1683 onward, he was mainly occupied as a suffragan bishop in the diocese and prince-bishopric of Münster and—after opposing the simoniacal

23 On Steno's research on generation, see Sobiech, *Ethos, Bioethics, and Sexual Ethics*, pp. 79–135.

24 BNCF, Gal. 291, fol. 180^{v}: "NB. Scilicet quod ex praecipuis in hac materia ipsius doctrinae [*erased*: materiis] fundamentis necessarium eruitur, non quod ipse sine ullo fortassis severiori examine ex solis consuetudinis humanae praejudiciis definivit."

25 See Kardel and Maquet, *Steno*, pp. 257–273.

26 Archivio della Curia Arcivescovile di Firenze (ACAF), LC 16, fol. 109^{v} (dimissorial letter, April 12, 1675).

27 OP, Sermo n° 43, pp. 360–364; here p. 364, lines 30–32: "omnem operam [...] omne tempus praeter spiritualia illi soli occupationi impenderim."

28 Maar, *Holger Jacobæus' Rejsebog*, p. 137.

election of the new prince-bishop of Münster on September 1, 1683—in the free city of Hamburg from 1683–1685 and, finally, in Schwerin (Mecklenburg) from December 1685–1686.[29] Eginhard Fabian surmised that Steno had realized that his theory of the Earth (Florence 1669) came close to "heretical ideas" like those of Giordano Bruno (1548–1600),[30] who had been burnt at the stake at the *Campo dei Fiori* in Rome on February 19, 1600. Steno surely realized that he had to defend the "innovation" of his geological theories against those who might fear they were irreconcilable with the Bible.[31] It is interesting to note in this context that Steno jotted down his first thoughts regarding the surface of the Earth—the sea and the formation of new land masses—on the evening immediately preceding his official conversion to the Roman Catholic Church, on December 8, 1667. He made those notes in the wake of a visit to Leghorn where he had observed the shore and its surroundings. When reading on the only preserved sheet of yellowish rag paper of his Florentine diary, one learns that same Wednesday, that "the places of Tuscany had been covered by the sea." Those notes are immediately followed by spiritual notes on from the next day, i.e. December 9, 1667.[32] On February 8, 1600, Bruno's *Opera omnia* had been placed on the Roman *Index librorum prohibitorum* (Index of forbidden books) by the Sacred Congregation of the Index, which meant that for an ordinary Roman Catholic they were forbidden to read.[33] But, on December 20, 1668, Steno had been granted the permission by Pope Clement IX (1667–1669) "to own and read forbidden books about medicine, anatomy and surgery, everywhere in Denmark, that in actual fact deal with religion, for a period of five years."[34] Steno's return to Denmark, which had been discussed in 1667, was questioned by his conversion from the Lutheran to the Roman Catholic faith. Moreover, as bishop and vicar apostolic, Steno continued to appreciate Descartes, even though on November 20, 1663, Descartes' *Opera*

29 Concerning the circumstances of Nicolas Steno's death and burial in Florence in 1687, see Sobiech, "The 'Capella Stenoniana' in Florence," pp. 73–76. Vol. II of Scherz's posthumous biography of Steno is yet to be translated into English.

30 Fabian (ed.), *Nicolaus Stenonis. Versuch einer Annäherung*, vol. 2, Berlin: Akademie Verlag 1988, pp. 161–162.

31 Steno, *Geological Papers*, p. 204, line 9: "novitate."

32 BNCF, Gal. 291, fol. 136^{r}, right column–136^{v}, left column, here fol. 136^{v}, left column: "loca Toscanae [...] mari essent tecta."

33 De Bujanda (ed.), *Index librorum prohibitorum 1600–1966*, p. 169.

34 Spruit and Totaro, *The Vatican Manuscript of Spinoza's* Ethica, p. 50: "licentiam [...] tenendi, et legendi libros prohibitos de re medica, anatomica, et chirurgica ubique in Dania vero tractantes de religione ad quinquennium."

philosophica (*Philosophical Works*; 2nd ed., Amsterdam 1650) had been placed on the Roman Index "*donec corrigatur*" (until corrected), meaning until all questionable passages had been clearly designated as scientific hypotheses.[35]

It is in the context of these various events and readings that we must consider the second excerpts from a philosophical work found among his Florentine papers. Hence, in his last fatiguing years, in the midst of quarrels in the Hamburg Catholic community, which was also cared for by the local Jesuit mission, Steno read Giordano Bruno's lampoon *Idiota triumphans seu de Mordentio inter geometras deo dialogus* published June 1586 in Paris, a dialogue between the characters Philotheus (Mordente) and Savolinus (Bruno himself).[36] Steno wrote down his notes on an Italian envelope which had been sent to him as bishop in Hamburg.[37] He seems to have written down his notes at the same time that he undertook his muscle studies, i.e. around 1684. In these muscle studies he mentions his friend during his university studies in Leiden, Baruch de Spinoza (1632–1677), whose *Opera posthuma* had been placed on the Roman Index some five years earlier, on March 13, 1679.[38] Thanks to the research done by Pina Totaro and Leen Spruit it is known that Steno turned in a report on Spinoza on September 4, 1677, to the Roman Holy Office (*Sanctum Officium*). A few weeks later, on September 23, followed the manuscript of the *Ethica ordine geometrica demonstrata*.[39] The reason for his action was that Steno believed that the use of the geometric method should be restricted to the natural sciences.[40] Therefore the question arises what might have motivated Steno to read the heterodox mathematician Bruno. Though it is difficult to ascertain

35 De Bujanda, *Index librorum prohibitorum*, pp. 281–282; see also Sobiech, *Ethos, Bioethics, and Sexual Ethics*, pp. 30–35.

36 Bruno, *Due dialoghi sconosciuti e due dialoghi noti*, XXI, p. 5. An Italian translation of the *Idiota triumphans* can be found in Bruno, *Il Dio dei geometri. Quattro dialoghi*, pp. 82–116.

37 BNCF, Gal. 291, fol. 87^{v}; the address reads: "All'Illustrissi^{mo} e Reverendissi^{mo} Signo^{re} Signo^{re} e Padrone Colendissi^{mo} / il Signo^{re} Niccolò Stenone Vescovo di Titiopoli / Amburgo." Cf. above, note 4.

38 De Bujanda, *Index librorum prohibitorum*, 850; EP II, Additamentum 24, pp. 949–951, here p. 950, line 42.

39 Spruit and Totaro, *The Vatican Manuscript of Spinoza's* Ethica, pp. 6–17, 25–26, 55–56.

40 Sobiech, *Ethos, Bioethics, and Sexual Ethics*, 119. In this context, one must take Steno's pastoral intent into consideration. He informed the Holy Office after Spinoza's death in February 1677, having evidently contacted him with the same intention in a private letter drafted before November 1671 (concerning the date, see Totaro, "'Ho certi amici in Ollandia': Stensen and Spinoza," p. 36, note 2). When Spinoza failed to respond, Steno published the private letter as an open letter in Florence in 1675, without however naming Spinoza as the recipient.

when exactly Steno became acquainted with Bruno's works—it is probable that Steno knew Bruno's works since his Italian years—, he seems to have been interested in the lampoon's content beceause of its relevance to similar research he had envisioned himself, just as it is the case in his muscle studies with regard to Spinoza.

The page with Steno's notes, excerpts and figures, which deal with an experiment with candles,[41] is divided into three columns on its front page, the second of which comprises the following lines: "Philosophy of an Idiot: Philotheus, the idiot, philomath [= lover of knowledge]",[42] and some lines below: "Analysis of the burning wax candle by means of philosophy without philosophy from [the answers] of an idiot alone, without [*erased*: a teacher] prescriptions".[43] The word "*mathesis*" is one of Bruno's "guides in religion" and important in his dialogue, which deals with "inspired ignorance" of people like Philotheus who speak in an inspired way without fully grasping their own speech.[44] Concerning the erased passage "a teacher," one has to bear in mind that Steno, as a theologian, emphasized the necessity of a teacher in matters of faith on the one hand, while, on the other hand, he also appreciated independent thinking.[45] In science, Steno advised his Copenhagen student Johann Valentin Wille (1651–1677) not to choose as a teacher anyone who cut a fiber before its orifices, components and connections were certain.[46] Steno looked even deeper: Already in the proem of his Paris *Discours sur l'anatomie du cerveau* (ca. February 1665) he pointed out that man, who was capable of thinking and research, had to admit complete failure in trying to grasp the structure of his own brain, the "most important organ of our soul". For the soul, Steno thought, believed to have penetrated—with the help of the brain with which it accomplished admirable things—everything around it so deeply that nothing in the world could limit its insight; "however", Steno added, "once it has returned into its own house, it is incapable of describing it and cannot recognize itself there."[47] According to Manlio Iofrida, Steno's empiricism here con-

41 BNCF, Gal. 291, fol. 87^{r+v}.

42 Ibid., fol. 87^{r}: "Philosophia idiotae. Philotheus, idiotae philomathes."

43 Ibid. fol. 87^{r}: "Analysis cerei ardentis per philosophiam sine philosophia ab idiotae [erased: responsis] sine [erased: magistro] praeceptis sola."

44 See Yates, *Giordano Bruno and the Hermetic Tradition*, pp. 296–297.

45 OT II, p. 323, lines 18–23. Steno's own conversion process from the Lutheran to the Roman Catholic faith is the best example of that. See Sobiech, "Blessed Nicholas Steno: Natural History Research and Science of the Cross," pp. 1–8.

46 Sobiech, *Ethos, Bioethics, and Sexual Ethics*, p. 159.

47 Sténon, *Discours sur l'anatomie du cerveau*, p. 79: "Cependant, quand elle est rentrée dans

nects with the topic of the "lack of transparency of the mind to itself" typical for philosophy in the latter half of the seventeenth century.[48] Especially the philosophical topics of knowledge and truth still remain something to be explored in Steno's manifold writings as philosopher, anatomist, geologist and theologian.

Though Steno took a clear stance in theological matters, he did not despise reading even "forbidden" authors, obviously motivated by the quest for finding some truth in them. Among the other Roman Catholic bishops in the Holy Roman Empire, he was the only natural researcher, who, furthermore, had done theological studies and published on theological matters. Perhaps this could also shed more light on the words brought forward by the Florentine Grand Duke Ferdinando II de' Medici (1610–1670) in the evening of December 8, 1667, at a private meeting with Steno which obviously took place in the grand-ducal *Palazzo Pitti* (situated in Oltrarno, Florence), namely that—according to the version of Steno's diary—"to preserve me [= Nicolas Steno] in the Catholic faith other persons will not be necessary, but the consideration of the blessings of God."[49] Steno seems to have been well-balanced deep down inside—besides his headaches in the wake of his conversion—,[50] and his late notes and excerpts of Giordano Bruno are like a mirror of his continuing interest in the questions of science and faith.

5 Conclusions and Outlook

Probably in preparation for his task as preceptor of the Florentine crown prince Ferdinando III de' Medici, Steno critically read the sixth volume *De anima bestiarum* (1671) of *Philosophia christiana* by the French Cartesian theologian André Martin. He contrasted Martin's conclusion to his own anatomical work on animal souls. Later, around 1684, as bishop and vicar apostolic in Hamburg, Steno also read Giordano Bruno's lampoon *Idiota triumphans* (1586), trying to determine its usefulness for doing natural science. His work on those texts can serve as point of departure for understanding Steno's position as philosophical thinker and scientist. His unedited papers can help deepening the topic. They

sa propre maison, elle ne la saurait décrire, et ne s'y connaît plus elle-même." See also Sobiech, *Ethos, Bioethics, and Sexual Ethics*, p. 65.

48 Iofrida, "Niels Stensen," pp. 890–897 and pp. 962–993, here p. 893.

49 BNCF, Gal. 291, fol. 136r, right column: "non opus aliis ad conservandum me in fide catholica quam consideratio beneficiorum Dei."

50 EP I, n° 30, p. 196, lines 6–12, and n° 34, p. 205, lines 9–13.

are the key to a more precise understanding of Steno's personality and scientific method. They clearly show that he did not stop thinking about the relations between science and faith when ordained in Florence and sent to Germany as a bishop.

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CHAPTER 11

Steno in Italy: From Florence to Rome

Pina Totaro

1 Introduction

The commentary literature has often insisted on how Nicolas Steno represented and incarnated a man of both science and faith. According to these interpreters, Steno is the exemplary expression of the difficult reconciliation of science and religion that tormented his contemporaries, in particular those who during these troubled years tried to strike a balance between the book of nature and the book of Holy Scripture, between the truths of reason and the truths of faith. The seventeenth century began with the violent rupture provoked by Galileo's condemnation—a condemnation illustrating the difficulties in finding common ground between biblical hermeneutics and scientific truth. Steno's role in this affair has been underlined by many authors who have considered his activities as a scientist and a theologian in the context of the project pursued by the Catholic Church to requalify itself as a promoter of the vast European movement generally referred to as "the scientific revolution." For those authors, Steno represents the possibility of being, at the same time, a man of culture and a theologian, a great scientist and a fervent believer.[1] Steno the great anatomist; Steno the founder of modern geology; Steno the catholic and

1 I use the documents gathered and published in the *Beatificationis et canonizationis servi Dei Nicolai Stenonis episcopi Titiopolitani* (*†1686*) *Positio super introductione causae et super virtutibus ex officio concinnata*, Osnabrugen: Ceccacci 1974 (hereafter *Positio*.) The Galileo affair created a dramatic and persistent tension between science and faith. Steno has, in the literature, come to represent resolution of that tension, and his thinking a new way of reconciling science and faith. Steno gained his greatest notoriety as an anatomist. At the same time, it was science that led him to reject Cartesianism and made him doubt the capacities of science. Even though Steno continued his research in anatomy and, from 1667 onward, in paleontology and geology, in the 1670s he "abandon[ed] scientific activity" (*Positio*, p. XVI). The crisis had begun when "his studies on muscles revealed the invalidity of old Galenic doctrines on the heart and muscles to him" (*Positio*, p. 19). Steno ascribed his later discovery that the heart was a muscle to "grace," as providing proof that Descartes' physiology and philosophy both lacked foundation (*Positio*, p. 27). When Steno, in 1678, wrote to Thévenot that "the curiosity of the world is vanity," it marked the beginning of a new phase in his intellectual evolution (*Positio*, p. 42).

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the obedient servant of God. All taken together, these images not only provides the portrait of a *savant* who was first a disciple and then a discerning critic of Descartes and Cartesianism. It also conjures up the broader image of a Church capable of showing a new face and open up to the most prominent tendencies of modernity.[2]

I have no intention here of lingering on the eternal debate about the nature and reach of this conception of the relations between religious faith and scientific revolution in the seventeenth century which is, at best, reductive. Indeed, when stated in terms of such opposition or reconciliation, the very question seems misguided. The relation between science and faith certainly did not follow a linear development throughout the same century. Moreover, in Catholic countries, relations between science and faith only existed because scientists upheld more or less complex relations to the ecclesiastical authorities. Incidentally, the itinerary of Steno itself went through complex phases where a plurality of ideas, encounters, voices and influences of all kinds gave rise to a multitude of new approaches and new interrogations. Nonetheless, the interpreters, editors and translators of Steno have tended to equip their author with two distinct souls in order to underline the perfect reconciliation between the distinct figures of the scientist and the theologian—a reconciliation, however, that remains at odds with the current division of Steno's biography into two periods: a "before" going up to around 1674 and an "after" from that date until his death.[3]

More importantly, however, Steno represents one of the most significant expressions of the crisis of Cartesianism. When going beyond the questions about how to understand faith or reason and their conformity to the canons of exegesis, Steno's intellectual biography first of all shows how much the anatomical studies that made him famous were also critically important because they

2 On these issues, and on the relations between science and faith in Catholic milieus, see Pesce, *L'ermeneutica biblica di Galileo*; Alexander, *Science et foi*; Grell and Cunningham, *Medicine and Religion in Enlightenment Europe*; Bucciantini Camerota (eds.), *Scienza e religione*; Damanti, *Libertas philosophandi*; Bucciantini, Camerota, and Giudice (eds.), *Il caso Galileo*. On the official position of the church in the Galilei affair, see Poupard (ed.), *La nuova immagine del mondo*. See also Festa, *Galileo. La lotta per la scienza*. The book by Miniati, *Steno's Challenge for Truth*, speaks of "reconciliation" of science and faith. Frank Sobiech rather speaks of Steno's "transition" from science to religion in *Herz, Gott, Kreuz*. See also Sobiech, *Radius in manu Dei*.

3 See for example KM. All editors of Steno's works maintain a distinction between the scientific and the theological works, between "his life and achievements as a scientist" and his work "as a Catholic bishop in Northern Germany between 1677–1686" (KM, p. VII).

marked the end of his adhesion to Cartesianism. These studies were, among other things, the result of transformations of the anatomical scene, changes in the study of the *fabrica* and the organic "machine" that had important consequences on the conceptual level, and the adoption of models allowing for the transition from the macroscopic to the microscopic level.[4]

If Steno the scientist saw and interpreted these changes, he also himself promoted these new developments. In this respect, his arrival in Florence marked a turning point in his life. Steno was welcomed and lodged at the Medici Court by the Great Duke Ferdinand II as a "*notomista danese di gran fama*" and a "*notomista eccellente*" as Lorenzo Magalotti writes to Alessandro Segni in 1666.[5] After his conversion, however, Steno did not seem capable of reconciling his interests in natural philosophy—spanning from physiology to embryology, epidemiology and geology—with his new commitment to religion and theology. He struggled especially to find a convincing solution to the problem of mind-body relations. The numerous works he wrote during the years he spent in the Grand Duchy, dividing his time between public dissections and religious activities, testify to his abandonment or rather progressive retreat from anatomical research as well as from European scientific debates. When Steno moved to Rome, the relationship was definitively broken. Rome marks the renunciation of anatomical research on the part of the priest and future bishop and a new attitude towards the Cartesian scientific model that he had adhered since the start of his activities as a scientist and anatomist. He now found the dualist solution perfectly inadequate and incapable of explaining the functioning of the organism and the real influence of the mind on the body. When moving from Florence to Rome, Steno lost his confidence in the very interpretive paradigm that had inspired all his studies. He suffered from the fact that the dualist solution was no longer a possible option, that it was no longer possible for him to pursue a unified conception, such as the one developed by the "impious" author Spinoza. Rome thus became the symbol of another decisive moment in Steno's intellectual itinerary, namely the end of his commitment to a model based on the possibility that the mind could direct the bodily machine.

4 See Baldini, "La scuola galileiana," pp. 383–468, 431; Baldini, "Gli studi su Giovanni Alfonso Borrelli," pp. 111–135.

5 Compare with the letter from Magalotti to Segni, 24 August 1666, in *Positio*, pp. 47–48.

2 Steno in Florence

As is well known, Steno resided in Tuscany on several occasions from March 1666 onward. Those were the years of his most intense scientific activity. Invited to stay by Cardinal Leopoldo, he entered into contact with the members of the school of Galileo and of the University of Pisa. In Florence, he frequented the circles of the Academies *della Crusca* and *del Cimento*. He spent time in particular with Francesco Redi, Lorenzo Magalotti and Vincenzo Viviani, and conducted "several beautiful experiments" combined with "a great number of speculations." He published important works on anatomy.[6]

Steno's conversion from Lutheranism to Catholicism in November 1667 has been largely documented by Gustav Scherz, in the biography recently translated into English by Troels Kardel and Paul Maquet.[7] During a second phase of his stay in the Grand Duchy, after returning to Florence in 1670, Steno once again entered into close relations with Italian and foreign physicians and anatomists. He regularly met with some of the best known personalities within European scientific culture at the time, including in particular Jan Swammerdam, Reiner de Graaf, Theodor Kerckring and Willem Piso. Among the numerous people staying at the Court of the Grand Duke Cosimo III, there were also former students from the medical faculty at the University of Leiden, former fellow students of Steno in the classes of Johannes van Horne, Franciscus de la Boë Sylvius, and Jacob Golius from 1660 to 1664. In Florence, Steno also made the acquaintance of the Dutch physician Tilman Trutwijn with whom he shared the practice of anatomy at the Hospital of Saint Matthew. But the theologian had now overtaken the anatomist. Trutwijn, who had stayed in the city of the Medicis since 1660, was converted by Steno about fifteen years later: "The conversion of Tilman to the Catholic faith was successfully completed due to Steno, and it provided a model of, and an example for, other conversions," as was reported by one of Steno's first biographers.[8] Among all the scientists present in Tuscany, Steno was however considered "much more illustrious": his reputation as a "famous anatomist" and as "one of the most judicious naturalists

6 One can consult, for example, the letter from Magalotti to Segni, 24 August 1666, or the letter from Redi to Viviani, 21 March 1667, in Negri et al. (eds.), *Niccolò Stenone e la scienza in Toscana*, pp. 25–27.

7 See Scherz, "Biography of Nicolaus Steno," in KM, pp. 7–338 (the translation includes only volume I, going up to 1677).

8 See the news about the conversion of "Tilmanno Truttwino Notomista," published in the 1775 biography by Manni, *Vita del letteratissimo Monsig. Niccolò Stenone*, p. 163.

alive today" was complemented by "remarkable and very polished manners."[9] The correspondence published by Sherz also contains an intense exchange of letters with the Grand Duke that testifies to the particular interest that Steno now, in the months between June and August 1671, attached to the results of his speleological explorations.[10]

A letter to the scientist Marcello Malpighi written in November 1671 gives several signs of the crisis that Steno the anatomist went through as a result of his scientific research. Here, Steno stresses the limits of philosophy and Cartesian science and expresses his doubts about the capacity of reason to explain certain natural phenomena, in particular the relation between the soul and the body (how the soul commanded the body was his primary scientific problem since it represented the most persistent difficulty in any dualist approach).[11] Speaking against certain tendencies in Cartesianism, interpreted as having full confidence in human rationality, Steno also severely criticizes those who exalt the capacities of the "natural light" and expresses his preference for "the objects of grace." From 1671 onward, then, Steno wanted to dedicate himself to the study of "all the weaknesses of philosophy" in order to establish exactly "what can be established about nature by it and what cannot and for which reason."[12]

An important element in Steno's intellectual biography during his years in Florence, while he was still trying to steer a difficult balance between his religious aspirations and his scientific interests, was his relationship to the librarian of the Medicis, Antonio Magliabechi who was, as the *Positio* puts it, "the only critical voice that Steno confronted."[13] The history of this often contradictory personal relationship allows us to observe what kind of study Steno undertook during those years, his main objects of research and the progressive decline of his scientific interests. Magliabechi met Steno in the spring of 1666 in Tuscany. The reputation of the Danish anatomist and physician had preceded his arrival. Cosimo, the son of Grand Duke Ferdinand II, wrote on this occasion to Magliabechi: "We have here among us the famous anatomist Mr Nicolas Steno who, as you know, has published the book on the glands," adding that the scientist was endowed with "much grace and extraordinary kindness accompa-

9 I translate here some passages from Targioni Tozzetti, *Notizie degli aggrandimenti delle scienze fisiche accaduti in Toscana* (1780; fac-sim. 1967), pp. 275–277.

10 See EP I, pp. 238–244.

11 See Steno to Malpighi, 24 November 1671, in EP I, pp. 249–250, transl. in Malpighi, *The Correspondance of Marcello Malpighi*, vol. II, pp. 597–598.

12 Ibid.

13 *Positio*, p. VII. See also p. XVII where they talk of "critical comments about the apostolate of Steno among non-Catholics."

nied by modesty."[14] Steno later left Italy, only to return in 1670–1672 and again in 1675–1677, during which years he resided in Florence. In the intermediate period, shortly before Steno's departure for Denmark in 1672, Magliabechi commented with some irony on Steno's excessive religious zeal: "I really had tears in my eyes from seeing his excessive humility and from hearing him speaking of divine matters," as he noted in a letter to the learned Genoan Angelico Aprosio.[15]

As is well known, during those years, Steno was alternating between scientific research and intense efforts to convert foreigners visiting Italy, especially those coming from Northern Europe. He was assisted in his scientific research by Giovanni Andrea Moniglia, Enrico Noris, Francesco Redi, Vincenzo Viviani, Carlo Dati and Giovan Batttista Gornia, all former students of Galileo. But the cultural politics of the Grand Duke would, at this time, radically transform the cultural orientation of Tuscany. Cosimo III now pleaded to undertake "no more studies" and even deemed them "useless studies," alleging that one should "rather read Scripture and the Church Fathers."[16] Steno supported Cosimo in this new approach and may, as Leibniz suspected, have influenced the Grand Duke (if it was not the other way round). Leibniz thus wrote to Melchisédec Thévenot in 1691:

> The Grand Duke has changed a lot. Before, he was curious about science and had even acquired great knowledge, but today he is renouncing upon all that. I cannot say if Mr Steno has contributed to this or whether it is rather S.A.S. [the Grand Duke] who has changed Mr Steno, as I think I have heard it said.[17]

Somewhat paradoxically for a scientist whose reputation as an anatomist long preceded his arrival in the Grand Duchy, after having been appointed as tutor

14 The original of the letter can be found in Firenze, Biblioteca Nazionale Centrale: Magl. VIII, 643, f. 120. On the relations between Steno and Magliabechi and other intellectuals in Florence, see also Totaro, "Niels Stensen (1638–1686) e la prima diffusione della filosofia di Spinoza nella Firenze di Cosimo III," pp. 147–168.

15 See Genova, Biblioteca Universitaria: Cod. E II, 2. The letter from Magliabechi to Aprosio of 17 May 1672 has also been published in Nordström, "Antonio Magliabechi och Nicolaus Steno," pp. 37–38.

16 Noris to Mezzobarba, 1680, quoted in Fabroni, *Vitae Italorum doctrina excellentium* (1780), vol. VI, p. 103.

17 The letter from Leibniz, written from Brunswich on 24 August (3 September) 1691, has been edited by A. Robinet in *Leibniz. Iter Italicum*, p. 220.

to Cosimo's oldest son Ferdinand in 1675, Steno was assigned to teaching "Christian philosophy" in order to better "serve God in the defense of the truth."[18] He hardly touched upon anatomy any more but dedicated more time and attention to the propagation of Catholicism and in particular to the conversion of "heretics." He guided the policies of the Grand Duchy which, at the time, was not expanding but rather at the beginning of a period of decline and cultural isolation. In a letter to Cardinal Leopoldo de Medici dated 8 December 1675, Lorenzo Magalotti testified to this sharp shift in Steno's interests. He even noted a hostile attitude toward those Protestants visiting Florence who refused to convert:

> As your Highness knows well, I have on several occasions incited Steno to content himself with giving other people a little more time. For the desire to conquer them immediately is a kind of spiritual sensitivity that satisfies his own zeal [but] that most often offends others and could compromise what one might obtain, giving [them] a reason to pull out.[19]

Steno's zeal was so great that he at times forced strangers reluctant to convert to leave the territory of the Grand Duchy and return to their country of origin. This was the case, for example, with Jacobus Gronovius who was stripped of his chair at the University of Pisa, according to Magliabechi's testimony. In one of his letters from 1676, the Medici's librarian also mentions Theodore, the son of the astronomer Stanislav Lubienetscki, who refused to renounce upon his religion and, for this reason, was obliged to interrupt his stay in Italy:

> We have been sent from Hamburg Mr Theodore, the son of Mr Stanislao de Lubienietz Lubieniecio Rolitsio, the author of a Theater of Comets printed in Amsterdam *apud Franciscum Cuyperum* in 1667. This young man (who is really very nice) lodged with Steno so that he may convert him and make him a Roman Catholic. Having failed to convert him […], the young man was denounced by the Inquisitor and forced to leave the town. The Grand Duke having given him money for the travel, the young man had to go far away from here.[20]

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18 See the documents published in *Positio*, pp. 217–234.

19 Magalotti to Cardinal Leopoldo, 8 December 1675, in Magalotti, *Scritti di corte e di mondo*, p. 170.

20 Magliabechi to Gronovius, 14 September 1676, München, Universitätsbibliothek: IV Cod. ms. 777, f. 115; *Positio*, p. 229.

Finally, between 1675 and 1677, Steno published six *Epistolae* in which, among other things, he discussed theology and ecclesiastical policy.[21] Here, he stressed that more attention should be given to the interpretation of Scripture, to the methods of convincing non-Catholics, and to the true meaning of the word "Reform," in particular that one should interpret it in the sense of a reform in morality and not in faith. Among these open letters figured the one he wrote to Spinoza and the *Epistola* in which he exposed the reasons why he had "abdicated his native heresy in the Court of the Inquisition."[22] In these writings, Descartes' philosophy represented both the crisis of the previously adopted scientific model and Steno's own crisis as a physician and anatomist. He was, from now on, convinced that it was impossible to offer scientifically based replies and solutions to the questions he had raised himself. Religious zeal replaced commitment to research,[23] to the point of arousing the irony of Pasquier Quesnel. According to the French Jansenist, Steno had fallen prey to "a fear of falling into the error of the heretics so out of proportion that it even makes him condemn things in them that are perfectly innocent."[24] During these years, Steno's task seemingly became more and more difficult, trying to maintain an unstable balance between the opportunities he had to dedicate himself to natural philosophy and the impossibility of adopting models that he

21 Steno's six letters, very difficult to find together in a single location (especially the first), were published in Florence *ex Typographia Nicolai Navesij* and *Ex Typographia Ioannis Gugliantini* between 1675 and 1677 under the following titles: *Ad novae philosophiae reformatorem de vera philosophia epistola*; *Epistola ad virum eruditum, cum quo in unitate S.R.E. desiderat aeternam amicitiam inire, detegens illorum artes, qui suum de interprete S. Scripturae errorem S. Patrum testimonio confirmare nituntur*; *Epistola ad virum eruditum, cum quo in unitate S.R.E. desiderat aeternam amicitiam inire, exponens methodum convincendi Acatholicum iuxta D. Chrysostomum ex eiusdem Homilia 33 in Act. Apostolorum*; *Scrutinium reformatorum ad demonstrandum, reformatores morum in Ecclesia fuisse a Deo, reformatores fidei non fuisse a Deo*; *Binae Epistolae ad Johannem Sylvium, Calvini dogmata Amstelodami docentem, altera de propria conversione, altera de infelici ipsius Sylvii ad geminum ipsi propositum syllogismum responso*.

22 On this letter, found by Meijer in the Hamburg *Staats- und Universitätsbibliothek* among the books of V. Placcius, see Cristofolini, "La lettera di Stensen: un falso d'autore," pp. 141–144.

23 On the notion of religious zeal, at times understood as a virtue, at others as narcissistic complacency and therefore secretly sinful, see the *Dictionnaire de spiritualité ascétique et mystique.*, vol. XVI, col. 1613.

24 Valéry, *Correspondance inédite de Mabillon et Montfaucon avec l'Italie*, vol. III, p. 358. See below in note 26 for the entire passage.

now deemed obsolete.[25] Hence, Quesnel continued in his letter to Magliabechi, "[Steno] seems to have applied himself more to anatomy than to philosophy and he fears Mr Descartes' philosophy as a novelty almost as dangerous as those in matters of religion."[26]

25 In am grateful to Sebastian Olden-Jørgensen for bringing to my attention a letter of 28 October 1674 from Steno to Pacichelli (printed in Pacichelli, *Memorie de' viaggi per l'Europa cristiana*, (1685), vol. II, pp. 547–550, and in *Positio*, pp. 215–216) where Steno's expresses his desire—"born in Italy and nourished in Rome"—to abandon science because it turned him away from God: "Ben è vero, che Iddio in Italia mi ha dato quella vita, senza la quale l'altra mi sarebbe stata materia d'infelicità eterna, e che Roma, Firenze ed altre città mi hanno fornito di nodrimento veramente celeste, per mano di più persone amate da Dio. È vero inoltre, che la Divina bontà mi ha mostrato diverse cose de' suoi maravigliosi effetti nel corso naturale; sicchè dopo viste tante Opere, e di Natura, e di Grazia, dovrei talmente applicarmi à coltivare la Vita datami in Italia, che la prima potesse diventare, come se non mai fosse stata sopra tutto quella Vita, che altre volte cercai nella lingua degli uomini. Vita, tanto più difficile da spegnersi, quanto men si scuopre il di lei pericolo, ricoperto con tanti superbi titoli, e con così copiosi esempi di persone, al giudizio del mondo, felici, de' quali titoli ed esempi gonfia la Fantasia, trattiene l'anima, mal grado di essa: e l'impedisce di voltarsi bene in sè, e nel suo Dio, per accorgersi, mentre ancora è tempo della vita, alla quale è stata fatta, e dal suo Dio viene continuamente chiamata. Ma, con tutto chè io riconosca la felicità dell'esser mio di prima, gli stessi oggetti, che dovrebbon servirmi per nodrimento della nuova, rinovano l'antica, ed in vece di tenermi viva la presenza di Dio, che così evidentemente parla, e nell'artificio delle cose naturali, e nelle facoltà dateci per ricercare, e nel gusto, che segue all'osservatione di qualche particolarità, mi tengo tutto attaccato alla materia, cagionando una scordanza con Dio, quel che fatto non è, se non per esser segno memorativo di Dio. Il che alle volte mi fa dubitare, se tiro innanzi, o nò lo studio delle curiosità, mentre veggo tanti momenti, che si potrebbero consegnare all'eternità reale, impiegarsi senza accorgermene à quell'eternità immaginaria dell'inchiostro. Ma troppo forsi mi stendo sopra una materia venutami così all'improvviso in mezo al legger nella sua, quel nato in Italia, e nodrito in Roma: il che, rinovandomi la memoria del sommo beneficio, ch'io ho ricevuto da Dio, mentre io vi hebbi la vita della Grazia, mi sono lasciato traspostare à scriver questo, senza riguardo ad altro." The editors of the *Positio* here correctly underline that "il suo spirito [i. e. of Steno] si sente ormai impedito da questi studi [scientific studies], di spiccare il volo verso le vette della mistica," whereas "l'abbandono totale della scienza per Iddio" will happen "a distanza di pochi mesi da questa lettera."

26 Valery, *Correspondance inédite de Mabillon et Montfaucon avec l'Italie*, vol. III, p. 358: "J'ai reçu, Monsieur, les deux lettres des 22 et 30 octobre dont il vous a plu de m'honorer, avec les imprimés de M. Sténon qui font paraître qu'il est bien converti à la foi catholique et qu'il est entré dans la piété de l'Eglise aussi bien que dans sa doctrine pour laquelle il fait paraître beaucoup de zèle. Il doit éviter seulement de ne pas avoir une crainte si demeurée de tomber dans les défauts des hérétiques, qu'elle lui fasse même condamner en eux des

The publication of the group of *Epistolae* by Steno in Florence testified to his turn to the exclusive pursuit of pastoral activities and an intense political agenda of conversions. As Magliabechi writes to the archbishop of Florence, "his zeal for the glory of God and the salvation of souls was such that he has sought out every occasion to obtain the friendship of Jews and heretics coming to conduct business in this city; and with his soft manners and his talents of persuasion, which are truly admirable, he has managed to convert quite a few."[27] However, wishing that Steno might soon return to anatomical research, Maglibechi also praised Steno's capacities to Gronovius, stressing that he was really "excellent in anatomy": "I can assure you that those who are most learned know that Steno defends the truth, but he cares little for these letters and would rather want him to dedicate himself to anatomy, where he is very strong indeed."[28]

While waiting to leave for Rome, Steno thus abandoned scientific research "leaving the road to perdition and taking the path of salvation."[29] Descartes and Spinoza were the catalysts of this transformation toward the "pious" Steno, because he did not see how he could adopt the Cartesian solution or embrace substance monism. He now had to liberate himself from Spinoza, his former friend, indeed a man with whom he had been "very close."[30] For Steno, Spinoza represented a past for which there was no present, an embarrassing presence. All ties had to be severed in order for Steno to liberate himself. But the figure of the philosopher would haunt him all along his sinuous path from Florence

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choses fort innocentes. Il peut avoir eu plus d'application à l'anatomie qu'à la philosophie et il a peur de la philosophie de M. Descartes comme d'une nouveauté qu'il croit presque aussi dangereuse que celles des matières de la religion; mais ces sortes de défauts ne sont pas tout-à-fait blâmables, quand ils viennent de la tendresse de la conscience, pourvu qu'on ne s'entête pas."

27 Cf. the following letter from the Archbishop of Florence, the Cardinal Nerli, to Innocent XI, in Manni, *Vita del letteratissimo Monsig. Niccolò Stenone*, pp. 263–265: "Il Sig. Stenone Danese […] abiurò nel Tribunale della Santa Inquisizione la sua nativa Eresia […]. Tanto era il suo zelo della gloria di Dio, e della salute dell'anime, che cercava ogni occasione d'insinuarsi nell'amicizia degli Ebrei, e degli Eretici, che per loro affare venivano in questa Città; e con le sue dolci maniere, e con l'efficacia della sua persuasione, la quale veramente è mirabile, gli è riuscito convertirne alcuni di quelli, e molti di questi."

28 Translation of a passage from a letter from Magliabechi to Gronovius of 12 May 1676, cit. in Nordström, "A. Magliabechi och N. Steno," p. 21. See also *Positio*, pp. 227–230.

29 *Positio*, p. 100.

30 Steno, *Ad novae philosophiae reformatorem de vera philosophia epistola* (letter first written in 1671; published in 1675), EP I, n° 61, pp. 231–238; *Positio*, pp. 156–163; p. 19: "L'amicizia con Spinoza però, fu per Stenone occasione di una crisi religiosa."

to Rome. Spinoza reflected the image of the Danish anatomist when he was still dissecting corpses and observing living beings, searching for a new scientific solution to the mind-body problem. From now on, however, Spinoza had become unacceptable for Steno, who could no longer reconcile his past with the truth that his own dissections had revealed to him.

At first, then, Steno sent a letter to Spinoza, seemingly aimed at converting him. He must have known that the project was doomed to fail. In 1670, however, Spinoza had published the *Tractatus theologico-politicus* in which the question whether faith should be the *ancilla* of philosophy, philosophy that of faith, or whether each should keep *suum regnum absque ulla alterius repugnantia*, had been put at the center of a controversy that was, at the same time, philosophical, ethical and political.[31] Steno had to take his distances and remove all suspicion of an ongoing friendship. An opportunity to do exactly this presented itself in 1675 when Albert Burgh, a young student of Spinoza, arrived in Florence. Steno approached him, harassed him and pushed him into a conversion. He then convinced Burgh to write a letter to Spinoza, the only letter to which the philosopher would reply with genuine disdain. This was however not sufficient. Spinoza continued to haunt him. Other young people, influential ones, shared Spinoza's ideas, frequented him and diffused his writings. Eventually, Steno ended up denouncing Spinoza to the Congregation of the Holy Office in a letter to which he appended a manuscript of Spinoza's *Ethics*, incidentally the only manuscript still extant today. The Congregation of the Index then put Albert Burgh, who in the meantime had been appointed neoconsultant, in charge of examining the doctrines on trial and, shortly after, the works of the philosopher were put in the *Index librorum prohibitorum*.[32] In his complaint, Steno gave an exposition of Spinoza's philosophy, speaking of it in medical terms as an epidemic, a contagious illness, a poison and an "evil" that had to be immediately "eradicated." The philosophy of the unique substance seemed to him more heretical and dangerous than that of two really distinct substances because of its skeptical implications. The 1675 letter to Spinoza here

31 On this point, see in particular chapter XV of Spinoza's *Tractatus theologico-politicus* entitled "Nec Theologiam Rationi, nec Rationem Theologiae ancillari, ostenditur, et ratio, qua nobis S. Scripturae authoritatem persuademus." The chapter begins as follows: "Qui Philosophiam a Theologia separare nesciunt, disputant, num Scriptura rationi, an contra ratio Scripturae debeat ancillari; hoc est, an sensus Scripturae rationi, an vero ratio Scripturae accommodari debeat: atque hoc a scepticis, qui rationis certitudinem negant, illud autem a dogmaticis defenditur" (Spinoza, *Opera*, vol. III, p. 180).

32 On the inclusion of Spinoza's works in the *Index librorum prohibitorum*, see Totaro, "Documenti su Spinoza nell'Archivio del S. Uffizio dell'Inquisizione," pp. 95–128.

marked an important moment in relation to his previous studies and institutional and professional contacts. Spinoza had become a ghost that constantly showed up on his path. Steno attempts to convert Spinoza and, later, his efforts to have his works condemned, clearly reflects a sense of urgency to avoid the implications of this new philosophy in terms of freedom of thought and of relationships between philosophy, science and theology. In his letter to Spinoza, Steno presented the emphasis on the criterion of demonstration as a form of obstinacy; he urged the philosopher to abandon *tua certitudo demonstrativa* and reproached him for championing a simple religion of the body instead of a religion of the soul (*corporum religio … non animarum*).[33] Steno, by contrast, embraced the unique criterion of certitude of faith which, *omnes demonstrationes superantis*, allowed him to rely only on facts *quibus authoris notitiam, & amorem acquirimus*.[34] We here see the polemics engaged against a Cartesian "reason" incapable of providing a certain model of demonstration. Steno is now convinced that he must renounce upon all attempts at approaching natural phenomena scientifically.[35]

These themes also appear in Steno's correspondence with Leibniz. During his stay in Hannover, Steno wrote to Leibniz that anatomical studies had convinced him to abandon scientific research; that God had thus, "through the anatomical discoveries," led him to "give up the philosophical presumption": "God saved me from all the subtleties of dangerous philosophers and all the finesse of politicians who are lovers of the same kind of philosophy."[36] As is well known, Leibniz complained repeatedly about Steno leaving anatomical research behind, since it was a discipline in which he could have obtained ever greater results.[37] Leibniz understood, in truth, that the heart of the matter was not the interpretation of certain conceptual difficulties in philosophy, but the metaphysical presuppositions involved in the definition of matter, body,

33 See Steno, *Ad novae philosophiae reformatorem*, in Spinoza, *Opera*, vol. IV, p. 296.

34 Ibid., p. 297.

35 In the essay *Defensio et plenior elucidatio Epistolae de propria conversione*, Steno explains how Providence saved him from the dangers of Cartesian philosophy ("Cartesii reformatoribus vel potius deformatoribus"). However, "Hobesianos potius dicendos vel Spinosistas quam Christianos" (*Positio*, pp. 85–88).

36 EP I, p. 366.

37 See, for example, Leibniz to Conring, 3 January 1678, and Leibniz to Conring, 19 March 1678, in Leibniz, GP I, pp. 184–185 and p. 193. See also Chapelain, *Lettres*, vol. II, p. 393: "Il efface certainement tous les anciens et tous les modernes en ce genre, et comme il est au-dessous de trente ans, on peut attendre de luy beaucoup de seures nouveautés pour le corps humain et de grands secrets pour la perfection de la médecine."

soul, substance. Hence, commenting on Steno's letter to Spinoza published in Florence in 1675 and entitled *Ad novae philosophiae reformatorem de vera philosophia epistola*, Leibniz noted that Steno's aim was to point out all the limits and imperfections of scientific research.[38]

At this juncture, there was no longer any room left for doubt in Steno's mind. The only true philosophy consisted in the faith established according to the principles of the Catholic Church, Roman and Apostolic: it was the Church that dictated what was true and what was false, even in science, indeed, especially in science. From there on, all difficulty vanished: the theologian dictated the truth to the scientist.[39]

Anatomy was doubtless the most appropriate field of research for Steno, a field where he made new scientific discoveries and provided unconventional solutions. Theology, however, did not seem to afford him the same success. The Apostolic Vicar of the United Provinces, Johannes Neercassel, wrote a letter to Guillaume Desprez, in which he pointed polemically to the limitations in Steno's theological knowledge, pointing out that Steno "has only studied theology in Rome and Florence, where they only teach what agrees entirely with the opinions of the Schools."[40] Consequently, we should oppose all attempts at interpreting Steno's intellectual biography as a successful experiment in "reconciling science and faith" as certain recent studies have suggested.[41] Instead, up until the time he went to Rome, the activities of the Danish scientist and theologian played out as an attempt to find a solution to how the soul governs the body, and they attested to his failure in providing a demonstration explaining how *cogitans et extensum uniuntur*, how the *principum movens* is joined to *quid movetur*.[42] The relationship of Steno with Leibniz is very important in this context.

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38 See EP II, p. 930, and *Positio*, pp. 156–163. Leibniz noted that "M. Stenon fut desabusé du Cartesianisme, quand il decouvrit combien le veritable corps humain est different de l'homme de des Cartes" (GP IV, p. 348).

39 Steno insisted particularly on theological themes in the letter to Spinoza. A copy of the letter was sent by Magliabechi, librarian to the Grand Duke of Toscany, to Placcius, professor in Hamburg. The same Placcius also received a letter about Spinoza from Leibniz on 14 February 1678. An excerpt of Leibniz's letter to Placcius can be found in Leibniz, A, II, i, p. 593.

40 *Positio*, p. 609. On Neercassel (1625–1686) and his relations to Steno and Jansenism, see Spiertz, *L'Église catholique des Provinces-Unies*; and Siebrand, *Spinoza and the Netherlanders*, pp. 132–147.

41 See for example Miniati, *Nicholas Steno's Challenge for Truth*.

42 See Steno, *Defensio et plenior elucidatio Epistolae de propria conversione* (1680), in OP I, pp. 380–400.

Leibniz's criticisms and the dismay he expressed with respect to Steno's change of profession are well known and have been studied in other contributions to this volume.[43] In his epistolary exchanges with Hermann Conring in particular, Leibniz regretted that Steno had distanced himself from the natural sciences and complained about his exclusive dedication to theological studies ("*Stenonium Episcopum doleo nunc a physiologicis studiis averti ad theologica*"). Later, he again vented his frustration in the disdainful assessment found in the *Essais de théodicée*: "He was a great anatomist and deeply versed in natural science; but he unfortunately gave up research therein," complaining that "he almost did not want to talk about the marvels of nature."[44]

In Steno's eyes, the marvels of nature remained largely unexplained. He considered with modern science with suspicion. For him, it remained inadequate and incapable of resolving the numerous questions that it raised. Steno's encounter with Jan Swammerdam is an example of these difficulties, connected with the crisis of Cartesianism. Steno had written a premonitory letter to Malpighi in which he related the dramatic tensions between natural science and faith troubling the Dutch scientist: "Mister Swammerdam has sent me drawings to send you if you are willing to receive them. He is at the point of abandoning all natural study […]. He had written a treatise on the same topic, but he tore it up and kept only the drawings: he is searching for God, but not yet in God's Church."[45]

Steno's attempt at converting Swammerdam coincided more or less with his attempt at converting Spinoza. The letter that Steno wrote to Spinoza in 1675—if indeed it really was a letter and Spinoza received it—remained unanswered, as one might expect, and when two years later Steno presented his complaint against Spinoza to the Holy Office, it was the last act in a unilateral encounter that opposed two main characters in the intellectual history of the seventeenth century who were once friends. But it also sealed Steno's departure from philosophy and science and gave final confirmation to his adherence to the primacy of faith. While recollecting his years of study at the faculty of medicine in Leiden, Steno admitted that he had had the occasion "to frequent in friendly terms this Spinoza, born a Jew, but of no religious profession,"[46] and with whom he had shared an interest in "the lessons of Descartes' philosophy." A very strong

43 On relations between Leibniz and Steno, see the paper by Lærke, *infra*.

44 For this famous passage, see Leibniz, *Essais de théodicée*, § 100, GP VI, p. 158.

45 Malpighi, *Opera medica, et anatomica varia* (1743), p. 59.

46 This quotation, as also the following ones, come from Steno's complaint against Spinoza kept as a manuscript in the historical Archives of the Congregation for the Doctrine of the Faith: S.O.C.L. 1680–1682, *Folia extravagantia* n. 2: "Libri prohibiti circa la nuova filosofia

connection between these two men of science was established as Steno could not prevent himself from acknowledging: Spinoza "came every day to my house to see the anatomy of the brain that I was doing with different types of animals in order to find the principal seat of movements and sensations." However, at this point, doubts about the relations between body and mind already began to manifest themselves and he would later say that God had oriented his mind to "the grace of faith." This divine intervention showed him the futility of research based on the conviction that "his understanding" was "the measure of all things." Steno had in fact discovered that there was no solution to the problem of the true origin of movement and sensation. He became convinced that reason was absolutely incapable of "demonstrating anything at all," be that through anatomical experimentation done with a scalpel ("with my hand, cutting things up") or philosophical speculation ("in the mind, with understanding"). Hence, according to the reconstruction he presented in his complaint, many years before, somewhere around 1663 or 1664, God had shown Steno "the true ways of nature" and all the vanity of those who confused the truth with the errors of science. When it came to the Cartesian philosophers, Steno asked: "If they have been wrong about things that are so simple what assurance can they give me when it comes to difficult ones?" Spinoza and his disciples were considered wretched people who lived "buried in the dirt of the senses," totally incapable of "elevating the mind to the consideration of spiritual things" with their "mathematical demonstrations." In short, Spinoza's philosophy, "engendered by sense and pride," had to be condemned and destroyed. Steno himself, on the contrary, aimed at demonstrating "the presence of the hand of God in the Catholic faith" through "the conversion of the sinful from one extreme to the other."

From the hands of one of those "sinful" people, probably Ehrenfried Walther von Tschirnhaus, Steno managed to acquire a manuscript copy of Spinoza's *Ethics*.[47] The delivery of this text to the Holy Office not only testified to Steno's aversion to a doctrine that "at least among the heretics has been widely propagated." It was the final stage in a process that eventualy led him to submit to the authority of Rome and to declare war against the claims of science of having penetrated the secrets of nature. Hence, if we look beyond a historiographical tradition trying to cast Steno as a striking example of the reconciliation of

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dello Spinosa". I have published this document in my "Documenti su Spinoza nell'Archivio del S. Uffizio dell'Inquisizione."

47 On this manuscript and its discovery in the Vatican Apostolic Library, see Spruit and Totaro, *The Vatican Manuscript of Spinoza's* Ethica.

science and faith, he rather incarnates an essential aspect of the crisis of Cartesianism. This explains his abandonment of scientific research, exposed by a premonitory sentence that effectively expresses his preference for the unknowable and irrational: "What is seen is beautiful, what is known is more beautiful still, but most beautiful by far are those things that we ignore."[48]

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48 Steno, *Proemium* (1673), OP I, p. 31: "Pulchra sunt quae videntur, pulchiora quae sciuntur, longe pulcherrima quae ignorantur."

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